

The AMSAT[®] Journal

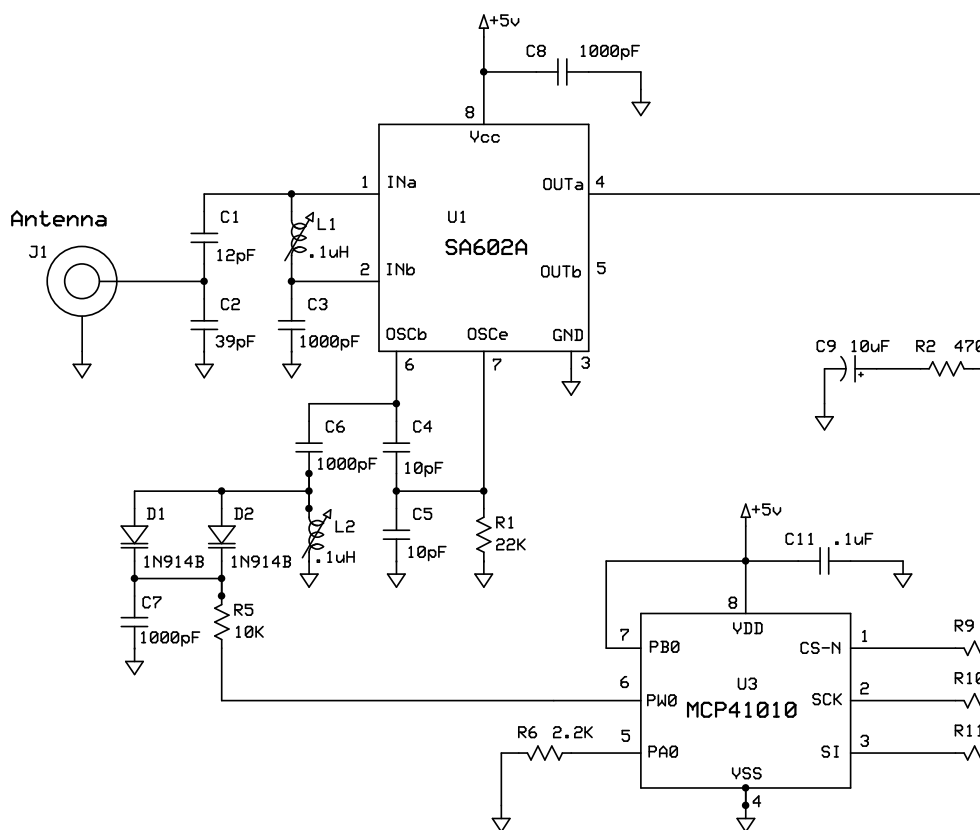


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Volume 31, Number 5

September/October 2008



Space Radio!

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AMSAT Announcements

New AMSAT-NA Officers

The AMSAT Board of Directors approved the following Officers at their meeting in Atlanta on 23 October 2008:

- **President:** Barry Baines, WD4ASW
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- **Vice President of User Services:** Gould Smith, WA4SXM
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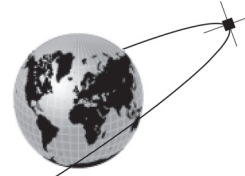
AMSAT's Mission

AMSAT is a non-profit volunteer organization which designs, builds and operates experimental satellites and promotes space education. We work in partnership with government, industry, educational institutions and fellow Amateur Radio societies. We encourage technical and scientific innovation, and promote the training and development of skilled satellite and ground system designers and operators.

AMSAT's Vision

Our Vision is to deploy satellite systems with the goal of providing wide-area and continuous coverage. AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups.





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This is the season of 'change' and AMSAT is no exception. As you probably know by now, AMSAT has undergone a change in leadership as a result of Rick Hambly's decision not to serve another term as President. At the Board of Director's (BoD) meeting in Atlanta, the Board voted to appoint me as President. I am honored that the Board has placed their trust in my leadership and I look forward to working with the board, the senior team, and our membership as we move forward into 2009. Along with a new president, the board now has a new member Gould Smith, WA4SXM, and board alternate Bill Ress, N6GHZ, which means that the BoD has undergone a 25% change in its membership of 7 BoD members plus 1 alternate following the 2008 BoD election.

During the board meeting on Thursday, October 23 and the Annual Meeting on Saturday morning, October 25th, we thanked Rick Hambly, W2GPS, for his four years of faithful and extensive service to AMSAT as our president. At the Annual Meeting, BOD member and treasurer Gunther Meisse, W8GSM, presented Rick with a plaque honoring him for his dedication.

During his presidency, Rick tackled a number of difficult issues and sought to move AMSAT forward in a number of areas. These included dealing with changes in the regulatory environment (orbital debris), establishing a relationship with University of Maryland-Eastern Shore that resulted in relocation of the AMSAT Integration Lab to Pocomoke, MD, working on the difficult issue of ITAR (International Traffic of Arms Regulations), revamping the AMSAT senior leadership team organizational structure, initial discussions with Intelsat on a possible 'rideshare' opportunity, and 'filling in' as our Web master when we lost the volunteer who handled that. Much of what Rick did was 'behind the scenes' activities that took many hours, required dedicated follow-up, and received little fanfare. Our sincere thanks go to Rick for his significant efforts to make AMSAT better. During the past four years no one dedicated such a significant portion of his or her life to AMSAT. Next time you see Rick, please take the time to thank him for his dedication to AMSAT and the work that he has done on our behalf.

As a new office holder, let me take a moment to introduce myself. I've been licensed since 1977 and currently hold an Extra

Class license. I joined AMSAT in 1981 and became an AMSAT life member in 1982. My first satellite contact was on AO-10 and I later enjoyed rag chewing on AO-13. When the 9k6 digital satellites were placed in service (such as KO-23 and KO-25), I established a digital gateway in Jacksonville, FL in 1993 that allowed local users to post files on these orbiting bulletin boards (using ground station software developed by John Hansen, WA0PTV, now W2FS). I became an Area Coordinator in 1991 and was appointed VP-Field Operations in 1995 by AMSAT President Bill Tynan, W3XO. When the AMSAT Integration Lab opened in early 1994, I began 'commuting' from Jacksonville to Orlando (300 miles round trip) to help with the construction of the Lab and then P-3D until the spacecraft was trucked to Atlanta in January 2001 to catch a flight to Guinea via Paris. During that six-year period, I drove over 25,000 miles to help at the Lab (about 83 round trips to the lab, or about 13 trips per year). The opportunity to work on the P3-D project was an inspiration for me and I certainly learned much just being at the Lab and watching the activity and participating as my time and my skills allowed. Following the launch of AO-40, I was thrilled to be able to operate through a satellite that I had helped build and had my 'fingerprints' on.

In 1996 I became responsible for managing AMSAT activities at the Dayton Hamvention - including coordinating our booth operation and managing the AMSAT Forum. In 2005, Gould Smith, WA4SXM, took over as Director-Field Operations.

In 1999 I was first elected to the AMSAT Board of Directors. In 2004 I was elected by the board to serve as a senior officer (VP-Marketing & User Services) and in 2006 I transitioned to corporate secretary & VP-Special Projects. As you can see, I've been an active AMSAT officer for a number of years that hopefully translates into experience and background that is useful in my current office.

My wife, Kathy, WD4ASX, and I now live in Westborough, MA, having moved when she accepted a position as Senior

continued on page 23 ...



Backyard Antenna Test Range

by Peter Carr, WW3O, wb3bqo@localnet.com

I also fly radio-controlled sailplanes so the neighbors are used to strange looking stuff being dragged into my backyard. The occasional use of 2.4 GHz as the downlink on AO-51 had peaked my interest in an antenna for that mode, which I activated last Spring. The equipment was basically COTS (commercial off the shelf) so I'd been wondering if it could do better. I decided to drag the equipment out into the backyard and set up a test range to evaluate the system and any changes.

The 2.4 GHz signal source is a carrier generator derived from a 32 MHz resonator with a line driver chip generating harmonics. The whole thing is powered by 4 AA size dry cells in a holder glued to the underside of the circuit board. This circuit was published in *The AMSAT Journal* in the July/August 2004 issue but has been revised. The goal is to provide a stable signal at about 2.4 GHz of low power. The antenna of the source is actually a resistor lead sticking up from the copper clad circuit board and it works

quite well. I was concerned about multipath reflections that might influence beam width measurements of the antenna under test. This proved not to be a problem since the houses nearby have non-metallic siding, the trees are still loaded with leaves and the surrounding hills have very little reflective properties.

The 60 cm dish with its dipole/downconverter was set up in the yard on a tripod with a wooden dowel as a support. The signal output is ≈ 144.00 MHz run through RG-6 75 ohm coax to a rotary step attenuator. The attenuated signal then goes to an ICOM IC-2100 FM 2M radio. The radio and bias T that feed voltage to the downconverter are powered from a 10-amp DC power supply fed by a long extension cord from the house.

There were two objectives of the test. First, I wanted to determine the amount of attenuation needed to produce a half scale reading on the ICOM S-meter. Normally, a meter is most accurate at full scale but since the ICOM isn't an "iron" meter it doesn't matter where it is set. Second, I wanted to swing the dish off beam and see how directive the reception pattern would be. The signal source was placed on a wooden fence post 55 feet from the antenna and turned on. I tuned the ICOM to 144.025 MHz, which peaked the signal from the dish and quieted the audio. The S-meter was pegged at full scale so I rotated the step attenuator until the meter came down to half scale. Now, any changes at the dish would be matched by a change at the attenuator to make the ICOM read half scale again. The change in decibel level as indicated by the attenuator dial would tell me if the changes made more or less signal at the radio.

The dish is going to be modified for a new feed and downconverter. I want to try various sizes of helix feeds as well as a Conifer downconverter that had been part of a Multipoint-Multichannel (MMDS) TV distribution system. The Conifer unit is in a big housing so must be mounted remotely from the feed with coax. There is also a difference in the gain compared to the present downconverter/antenna. Lastly, the number of turns of the helix and the backplane reflector cup have to be positioned at the dish focal point. This is best done by experiment and the test range is perfect for this. At the end of the day I want to have hard numbers to evaluate differences over the present setup.

The second part of the test was to swing the dish away from the signal source and watch the ICOM S-meter. I continued moving the dish off beam until it took 3 dB lower attenuation to bring the S-meter back to half scale. The angle, surprisingly, was over 45 degrees. Since a wide beamwidth means lower forward gain it showed that the dish needs to be optimized. This data was also noted for future comparison.

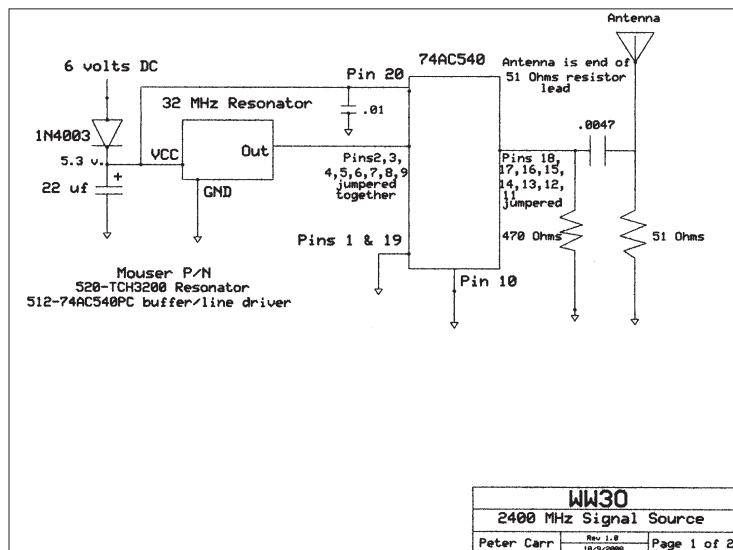


Figure 1: This is the schematic of the 2.4 GHz signal source. The resonator and line driver part numbers are Mouser part numbers.

Back in college we were taught to draw diagrams and make notes in copy books so that we could compare results of experiments. The advent of digital cameras makes all that so much easier now. I decided to take pictures of the setup so that future tests would be done under exactly the same conditions.

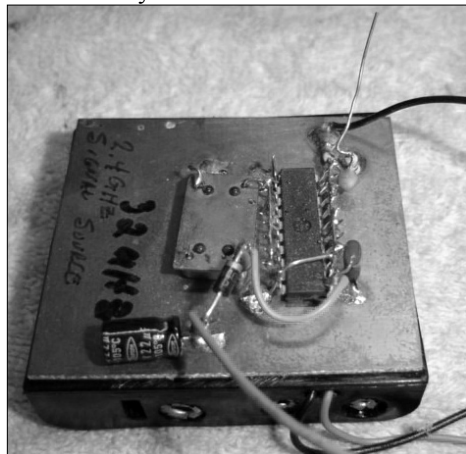


Photo 1: This is the 2.4 GHz signal source. It is built on a 4 inch square piece of clad circuit board that acts as a ground.

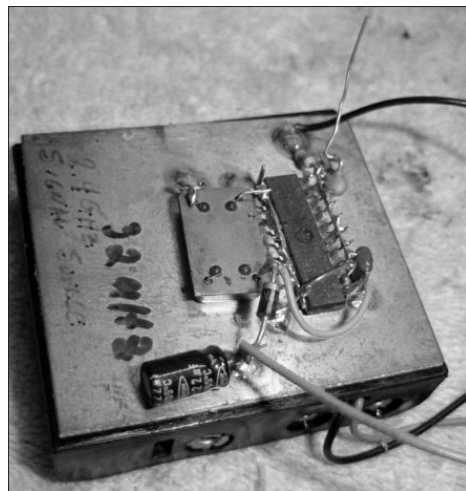


Photo 2: Another perspective of the dead bug construction of the signal source. The power wires come from a 4-cell AA dry battery holder, which is hot melt glued to the reverse side of the circuit board.



Photo 3: The ICOM IC2100 2M radio is receiving the 2.4 GHz signal as 144.02 MHz from the downconverter at the dish.



Photo 4: The ICOM signal is reduced to mid-scale on the S-meter using a rotary attenuator. Most any attenuator, rotary or slide switch type, would work equally well.

As I mentioned previously, the signal source antenna is a resistor lead straight up over the circuit board ground plane. The circularity or polarization of this arrangement is questionable. I tried positioning the dish and feed 90 degrees from the initial position looking for a 3 dB drop in signal. There was no significant change in the S-meter reading. Under these crude conditions I was not able to duplicate the expected cross polarization signal drop.

And so it begins. The information gathered from this quality backyard time is the foundation of a learning curve. Each successive experiment will, no doubt, provide entertainment for the neighbors while helping me to greater understanding.

References

Circular Polarization and OSCAR Communications by B. Glassmeyer; *QST Magazine*, May 1980.

A 60-cm S-Band Dish Antenna by J. Miller; *The AMSAT Journal*, Mar/Apr 1993.

A High-Gain 2.4 GHz Helix Antenna by T.J. Nelson, (Radio Setup Notes), tjnelson@brneurosci.org

Receiver Performance Tests, *The 2007 Radio Amateurs Handbook*, Page 25.41 to 25.42.



Photo 5: The dish and tripod mount are aimed at the signal source across the backyard.

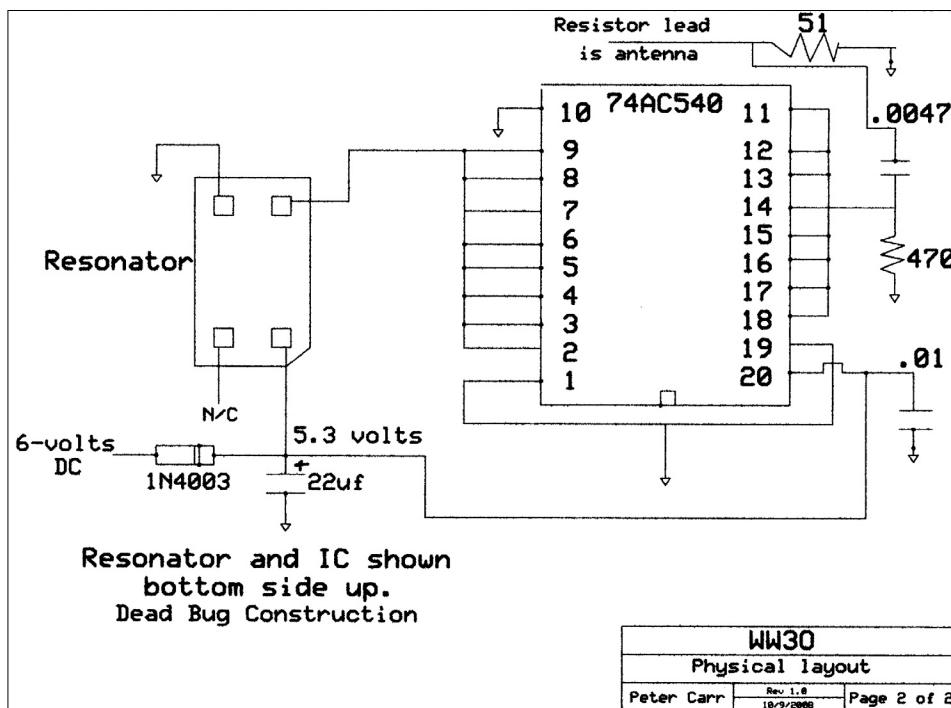


Figure 2: This is the functional diagram of parts placement. The resonator and line driver are shown bottom side up so the leads can be easily connected. Once wired, the parts stay close to the circuit board but a dab of hot melt glue prevents parts shifting.



Building a Beacon for 2401 MHz by John Jamient, W3HMS, and Charlie Heisler, K3VDB

Introduction

Since we have not had an HEO Satellite for quite some time to use as a signal source, we thought a beacon that operates 24/7 might be useful to folks around south-central Pennsylvania.

Overview

The microwave community makes extensive use of beacons for equipment and propagation checking on all bands from 6M-24 GHz so why not do the same for satellite users? This seems like an excellent idea so we began building a dual band beacon for 1296.064 MHz with horizontal polarization and a 2401 MHz beacon with circular polarization both in the same enclosure.

The “we” in this case is Fred Lowe, W3MMV, Joe Lockbaum, WA3PTV, John Jamient, W3HMS, and Charlie Heisler, K3VDB, (AKA as the Microwave Lunch Group). We defined the tasks to be completed and the purchases to be made then shared the plan with our group. John, W3HMS, has operated a Kuhne Electronics beacon on 10 GHz for about 6 years and has been pleased with the dependability of their products, which is consistent with their other products that he uses for contesting on VHF, UHF and microwave.

Technical Summary

The heart of the two beacons is the Kuhne Electronics (DB6NT) of Germany “Bakensenders” for each band. Each was ordered with the frequency specified. Each uses F1 FSK keying via a classic “make and break” keyer, which promotes better short-term stability. The frequency will change a few KHz over time as the crystal ages. W3MMV volunteered to fabricate the horizontally polarized Alfred slot antenna for 23 cm from scratch, as did K3VDB for the 13 cm circularly polarized Lindenblad antenna. The slot antenna gain is about 4 db and the Lindenblad about 3 db and both antennas are housed in radomes. The 10 GHz beacon experience told us that we wanted to use a WW2R keyer with telemetry so we could remotely monitor the health of each beacon, which is keyed by the same keyer. We use two blowers both for airflow and dependability, turned on and off by a thermostat set to about 80 degrees F. To house both beacons, all the equipment is mounted in a waterproof box designed for the electrical trade. A single coax cable feeds 13 VDC to the beacons from the power supply located in a building at the base of the tower. The 23 cm beacon has an output power of 1.5 watts and the 2401 MHz beacon’s output is 1 watt.



Figure 2: 2401 MHz Lindenblad antenna in the radome.

any sensor value, which can be expressed in the range 0-5 VDC.

Beacon Message

We decided we wanted the beacon to send “W3HZU/B W3HZU/B FN10PA FN10PA QSL to w3hms@aol.com (then the telemetry in 4 groups of three numbers like; First, approximately 10 seconds of key down, (then the TLM) 056049009032, then recycle.

Channel 1 = DC Bus Voltage. The DC voltage on the beacon bus is calculated by a formula a bit too complex to calculate in your head, but easy to define in an Excel spreadsheet for common values. Let’s say you copy the first group of 3 number 056; that = 12.60 VDC at the beacon input.

Channel 2 = Inside Temp. The second set of 3 numbers is the thermometer mounted on the beacon transmitter cover. One half of the temperature in °F is sent in CW. As an example, if 049 is sent then $049 \times 2 = 98\text{F}$. The temperature sensor is the reasonably priced LM34DZ.

Channel 3 = Vent Fans. If the two vent fans are on, the decoded numbers will be more like 246 than 000, as the latter indicates the fans are off. The fans cycle on and off about

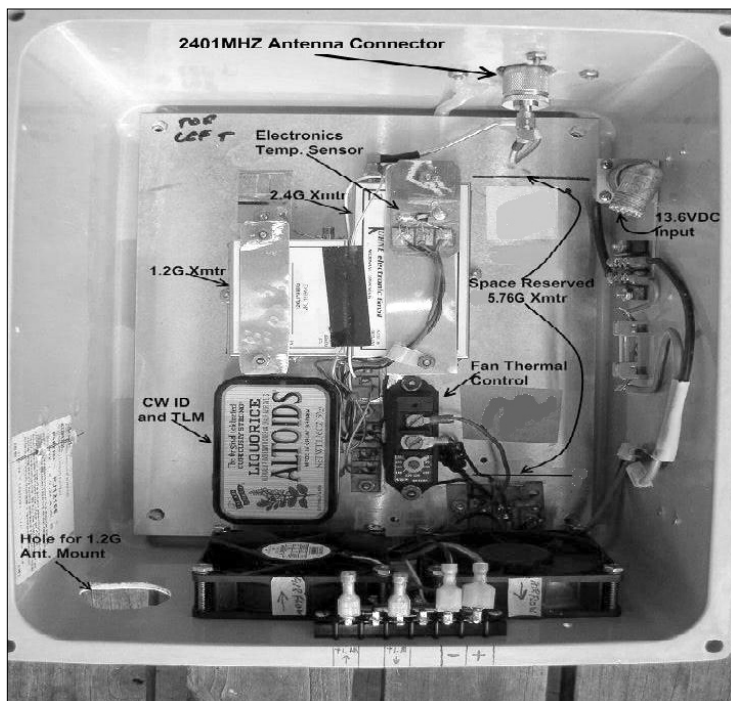


Figure 1: Inside the beacon box before the addition of the third beacon.

Telemetry (TLM)

TLM has 4 channels of information. It was designed and built using a PIC microprocessor. Doug Robinson, G4FRE/WW2R, in Texas, programmed the PIC processor. All the details are available on his Web site: <http://www.g4fre.com/kits.htm>. The telemetry keyer is called an “Intelligent Keyer” and it is can be seen on his site under that title with schematic. Doug programs the desired message at the time of purchase. It is possible to send



Figure 3: 1296 MHz Alfred 8 slot antenna in radome.

every 6 minutes at an outside temperature of 70 °F.

Channel 4 = Outside Temperature. The last 3 numbers are temperature outside the beacon box and decoded as defined above for the inside temperature.

Performance

The beacon entered service at a temporary site on 6 June 2007. Initial tests from the W3MMV QTH back yard (in a tree hung by a rope) confirmed good operation, but the signals were weak at any real distance. K3VDB was able to obtain temporary permission to mount the beacons at a height

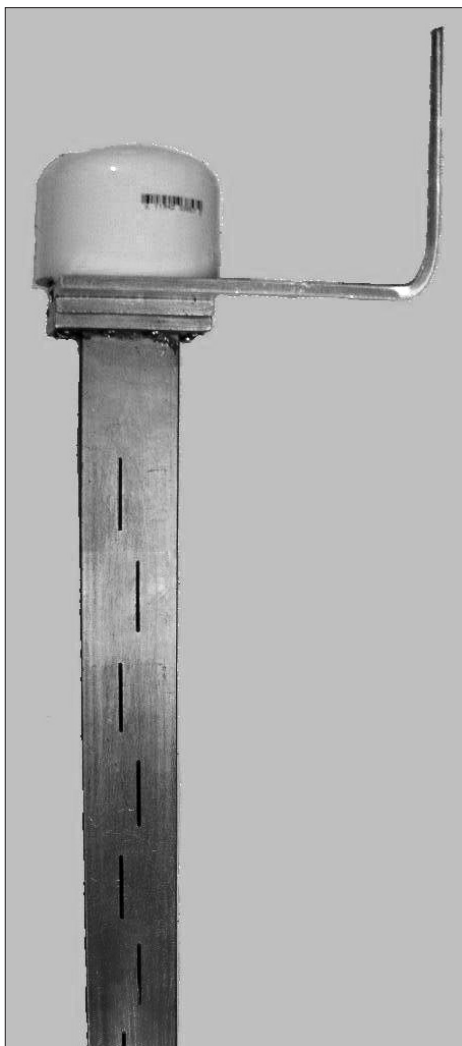


Figure 4: 5760 MHz Alfred 8 slot antenna without radome.

of about 1130 FAS on a tower near Red Lion, PA, grid square FM19qv.

The beacon signs W 3 H Z U and FN10PA as that is the ultimate destination on their 200 ft tower at about the 150 foot level. We have had excellent reports on the 23 cm beacon out to about 100 miles. The 2401 MHz beacon has been heard at about 75 miles. The Weak Signal Group has asked why not 2304 MHz, and we have explained the needs of satellite operators at 2401 Mhz. An Excel spreadsheet has been developed by K3VDB to record telemetry

data in a scientific manner, and is available on request.

Cost

These beacons are quality instruments and as such are not cheap, HI! We will be happy to discuss this aspect with serious prospective builders.

Photos

We have included photos of the complete beacon package with the two antennas.

Signal reports are welcomed and for further information and technical details, please contact Charlie Heisler, K3VDB, at e-mail k3vdb@amsat.org or John Jamient, W3HMS, at w3hms@aol.com.

Update April 2008

Recently we have added a third beacon to the box. Room was provided for in the original build as shown in Figure 1. This beacon is on a frequency of 5760.215 MHz. It was also purchased from DB6NT. It has an output of 210 mW and also uses a WW2R keyer. The antenna is an 8 slot Alfred antenna also built by Fred W3MMV.

TLM on the 5760 MHz Beacon

Example: You may receive CW with telemetry of 134 065 000 000. The 5760 MHz beacon TLM is decoded a bit differently than the other two beacons as described below.

Channel 1 = DCV on this beacon bus. No calculation is needed. 134 = 13.3 VDC

Channel 2 = Transmit mW RF power out. This calculation is easier done on a calculator, suffice it to say that if the second

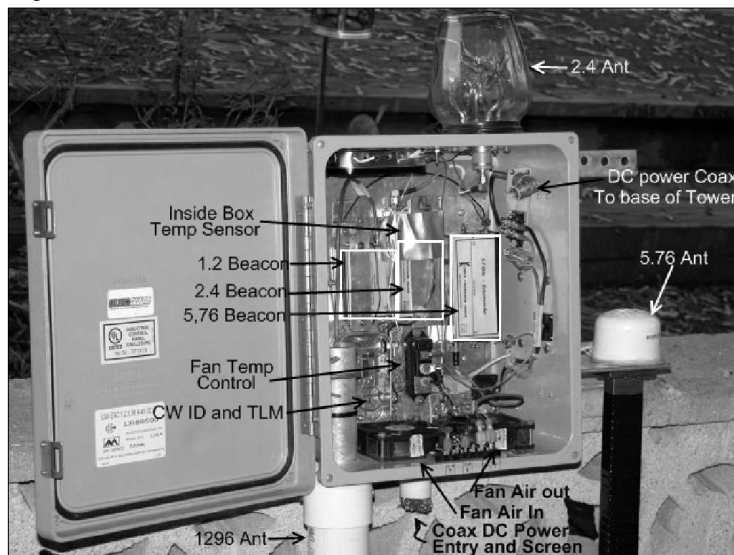


Figure 5: Inside the beacon box with antennas after the addition of the third beacon.

continued on page 10 ...



A 52-Turn Helix Antenna for S Band that Overperforms

by Clare Fowler, VE3NPC, ve3npc@amsat.org

The final test of an antenna is how well it performs in on air operation.

Over the years, to accommodate the many satellite frequency modes, I had installed two az/el rotor systems with some duplication in antennas. With no prospect of a high orbiter for some time, and the fact that I had constructed a 52-turn helix antenna for S band that appeared to provide close to the theoretical gain, I decided to replace my 1.2 meter dish with the 52-turn helix and consolidate all the currently required antennas on one boom with one az/el rotor unit. The question was, would the 52-turn helix with the cup reflector perform in actual satellite operation as well as my test range measurements indicated it would?

Between August 15 and 17, 2008 when AO-51 was in mode V/S, I was on for thirteen passes. Three of them were low eastern passes over the Atlantic where I was the only one on and I talked to myself throughout the pass. On the ten other passes I made a total of 31 QSO's involving 15 individual calls. Generally there were no more than two or three of us on during a pass so I was able to converse for most of the 10 to 14 minutes of the pass. Passes to the west below 15 degrees elevation are obstructed by a large maple tree hindering some QSO's. Signal levels varied from an S1 to S9 + 10db. The S1 signals were near AOS and LOS where the range and squint angle are greatest and the S9+10db signals were near overhead passes where the satellite is closest and squint angle

is low. While at times QSB was several S units, at no time during a pass from AOS to LOS did I lose the signal in the noise with the exception of when the signal path was obstructed by the tree. Signals above S3 were full quieting. While indirect on air antenna comparisons are very subjective, I am very pleased with the performance of the 52-turn helix, as constructed, and have no misgivings about giving up the 1.2 meter dish. Having made hundreds of SSB S band downlink QSO's on AO-13 and AO-40 with the 1.2 meter dish, I have no hesitation in saying that the helix, while not equal to the dish, would have performed very well for reception on those amateur satellites.

My previous papers published in *The AMSAT Journal* [1], [2], have covered test range comparison measurements made between several configurations of helix antennas. These tests resulted in two significant conclusions that are not in agreement with and contradict information given in many Amateur Radio publications. "Maximum Gain" dimensioned antennas did not give the predicted increased gain and helix antennas that appeared to provide close to the theoretical gain were constructed with up to four times more turns than the published limitation of from 12 to 16 turns.

Not having a reference antenna with a known gain I could not make absolute gain measurements. I measured the difference in gain between antennas with more or less turns. If you double the number of turns of

a helical antenna, according to the Kraus formula, the gain should double and the difference would be +3 db. Double the length again, or four times, and you should see a difference of +6 db. Halve the number of turns and the gain would be -3db.

As discussed in the paper referenced in [1], the comparison gain measurements on a 52-turn helix with a flat reflector had 1.5 db gain less than expected while later measurements with the 52-turn helix discussed in the



Photo 1: Conductor mounting post on fiber glass boom.

paper referenced in [2] with a cup reflector 1 wavelength in diameter and with a lip $\frac{1}{4}$ wavelength high showed an improvement of 1.4 db. The improvement in gain provided by the cup on the 52-turn helix overcomes the previous 1.5 db loss and results in a gain which would appear to be close to the theoretical.

The calculated gain of my 1.2 meter dish, assuming 50% efficiency, is 26.7 db.

The calculated gain of the 52 turn Kraus design helix is 22.4 db.

This gives a gain difference of 4.3 db less for the helix. High gain relates to relatively large size and the single-52 turn helix does not have the aperture area of the 1.2 meter dish.

Note that I have calculated the gain to a tenth of a db. In the real world this is unrealistic. The assumed dish efficiency of 50% may or may not be correct. The texts just seem to pull this out of thin air. Considering all the various dish parameters including feed illumination, dish surface structure, adherence to parabolic, etc., the efficiency could be a bit higher or considerably less resulting in a gain of up to 0.5 db more or a db or so less. The same holds true for the helix. Browsing the test range measurements made on antennas at the various microwave conferences can be an eye opener on how poorly some submitted antennas perform.

I constructed the 1.2 meter dish with a helix feed for mode S reception for AO-13 and then later used for AO-40. My satellite antennas are located on the flat roof of my 3 story house. My ham shack is immediately below so that my feed lines are nominally only 11 meters in length. The preamp and down converter were Down East Microwave

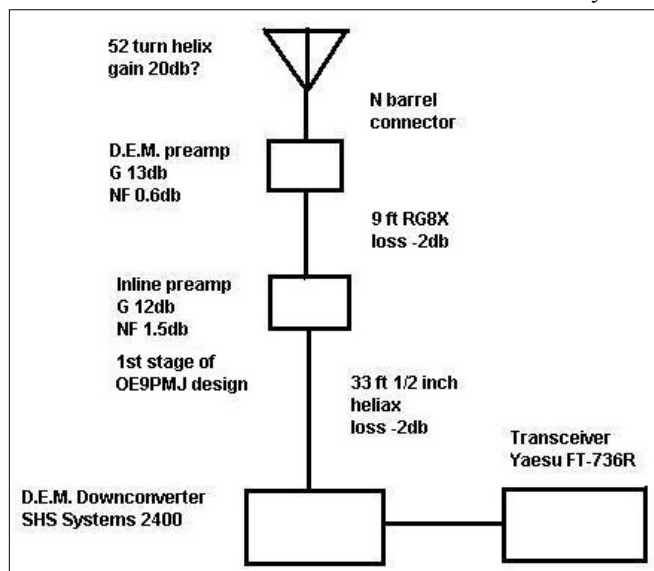


Figure 1: Block diagram of VE3NPC mode S receiving system.



Photo 2: Reflector cup, conductor feed and quarter wave matching plate.

kits of PC boards and components. Originally the down converter was put in an enclosure and placed at the foot of a small tripod and pipe mast. However the large frequency drift with temperature made operating difficult. So I constructed another preamp and placed it inline at the foot of the tripod where the



Photo 3: Back of reflector cup with N connector and boom mounting angle brackets.

down converter had been. I used 1/2 inch heliaco from the inline amplifier to the ham shack. I could then put the down converter inside where the temperature is more stable. This system has worked very well for 15 years during which I made several thousand mode S QSO's on AO-13 and AO-40. My current mode S receiving system is shown in Figure 1.

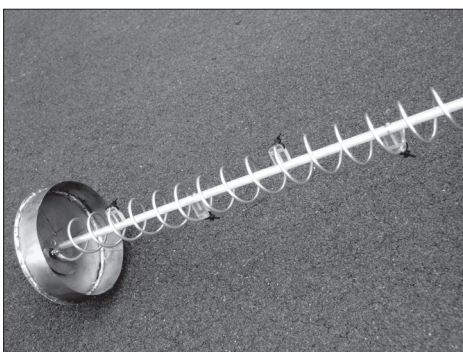


Photo 4: First 15 turns, reflector cup, quarter wave match and first four conductor mounting posts of the 52-turn helix antenna.

To minimize strain on the rotor system I keep the antennas light in weight with a low wind profile and mounted on the cross boom at the balance point. For this and other reasons I do not favor the use of PVC pipe but use fiber glass stake material for antenna booms and aluminum grounding wire for the conductor. The aluminum wire is rigid enough to hold its shape and stands up to the environment. My 70cm helix antennas using fiber glass stake booms and aluminum wire for the conductor have been in use for 16 years and withstood a major ice storm.

The main drawback in using aluminum for the conductor is that it cannot easily be soldered to the center pin of a type N connector. I got around this problem by flattening the last 3/8 inch of the aluminum wire with a hammer on an anvil and drilling a hole in the center for a 4/40 screw. The head is cut off of a 1/2 inch 4/40 brass screw. One end is ground down and soldered into the pin of the N chassis connector. The end of the aluminum wire with the hole is held in place on the screw with a brass nut.

For a frequency of 2401 MHz the circumference of one wavelength is 12.495 cm so the diameter is 3.977 cm. You are not going to be accurate to 1/100 of a cm let alone 1/1000, so round the diameter off to 4 cm. Much of the literature indicates a larger diameter than this. A circumference greater than one wavelength will work, but no better, for helical antennas with up to about 15 turns. Over 15 turns, if the circumference is greater than one wavelength, the main lobe distorts and the side lobes increase in size [1].

To realize increased gain with increased number of turns for helix antennas with over about 15 turns, the circumference



Photo 5: Low noise preamp in home built enclosure, antenna and mounting saddle. All mounting supports are fiberglass and plastic material.

should be held to one wavelength and the pitch angle to 12.5 degrees.

52-Turn Helix Antenna Construction

The boom is a nominal 1/2 inch wide x 1/4 thick x 5 ft long fiberglass stake that is sold in the fencing department of home building stores. The conductor is supported by 15 support posts. Holes are drilled in the fiberglass boom for the posts which are held in place with 1/2 inch #4 stainless steel self tapping screws. For a pitch angle of 12.5 degrees the spacing between turns is 2.77 cm. The first post is located 8.0 cm from the reflector. The remaining posts are positioned 3-1/2 turns apart at 17.7 cm, 27.4 cm, 37.1 cm, 46.8 cm, 56.5 cm, 66.2 cm, 75.9 cm, 85.7cm, 95.3 cm, 105.0 cm, 114.6 cm, 124.3 cm, 134.0 cm, and 143.7 cm. from the reflector. The conductor support posts are cut from 1/4 inch thick Lexan plastic. This plastic is weather resistant, very strong and is easy to saw and drill. The posts are 11/16" (18 mm) high, 1/2" (12 mm) wide, 1/4" (6 mm) thick. A half round slot is filed at an angle into the top of the post to accept the conductor. A hole is drilled diagonally through the post for a 4 inch black automotive nylon cable



Photo 6: VE3NPC home built satellite antennas: 2 x 6 element 2 meter quagis, 4 x 27 turn 23 cm helix, 2 x 10 turn RH 70 cm helix, 1 x 10 turn LH 70 cm helix and 1 x 52 turn 12.5 cm helix.

tie to strap the conductor to the post. The top corners of the post are rounded off with a file so that the cable ties will hold the conductor firmly in place. Helix antennas generally do not require high dimensional accuracy and so lend themselves to home construction.

The reflector cup is constructed using double sided circuit board and brass sheet. The diameter of the cup is 12.5 cm which is one wavelength. The reflector circuit board is cut oversize so that the diameter of the cup when the brass sides are soldered to it is 12.5 cm. The lip is 3.1 cm high which is a quarter wavelength. A slot is cut into the center of the cup circuit board material for the boom to pass through. The cup is fastened to the boom with two brackets cut from 3/4 inch aluminum angle stock.

The 1/4 wave matching section [3] comprises a curved piece of brass sheet that lies under the first quarter turn of the helix. It is held in place and grounded with the two flat head stainless steel screws fastening the type N chassis mount connector. The other end of the curved brass plate cannot be left floating

but must be grounded with a short U strip of brass soldered to the brass plate and the reflector board directly underneath. The type N connector is set back from the circuit board reflector with an aluminum spacer so that the space between the matching plate and the end of the helix conductor is approximately 3 mm.

The helical conductor is formed by close winding the aluminum wire around a length of 1 5/16 inch (34 mm) OD ridged PVC pipe. It is then pulled out to match previously made marks spaced 2.77 cm apart on the pipe. The close winding will spring out slightly but when pulled out it will tighten back onto the PVC pipe and give the desired diameter of 4 cm between the wire centers.

To adjust the SWR, the 1/4 wave matching plate is adjusted up or down below the conductor. Ideally this should be done with suitable instrumentation. It should not be difficult to adjust for very close to an SWR of 1:1. If no instrumentation is available, adjust the spacing so that a 4/40 screw just slides evenly along the space between the ground

plate and the conductor and the SWR should be 1.5 or better.

I like to mount all my antennas at their balance point on a non-conducting cross boom.

As the 52-turn helix antenna is comparatively small and light weight I used several pieces of the fiberglass stakes to support it and the low noise preamp between two fiberglass boom support posts. Individual mounting methods will vary and ideally it should be several wavelengths away from other antennas.

References:

- [1] Real World Helix Antenna Comparison Measurements, Clare Fowler, VE3NPC, *The AMSAT Journal*, May/June 2006.
- [2] Additional Real World Antenna Comparison Measurements, Clare Fowler, VE3NPC, *The AMSAT Journal*, July/August 2007.
- [3] The Development of a Quarter Wave Match for Helical Antennas, Clare Fowler, VE3NPC, *The AMSAT Journal*, Nov/Dec 2005.

Beacon - continued from page 7 ...



Figure 6: Inside the beacon box with some notation.

group of three numbers is 065 = 213.2813 mW.

Channel 3 = Spare at this time.

Channel 4 = Spare at this time.

A word about the ID Message. When we originally ordered the beacon(s) ID'er, the plan was to have them located on the W3HZU tower in Grid FN10pa as the ID message says. However we found another tower location with a ham friendly owner attitude, that was more convenient and a good look in all directions. We put it on

this tower for test, but it has worked out fine, so at this time we have no plans to move it. Regardless of what the ID says, it is now located just North of Red Lion, PA in Grid FM19qv. At some point we may update the IDer's call sign and grid.

Signal Reports

We hope these beacons will be useful to the amateur community and we regret some satellite radios will not tune far enough to receive all three

of our beacon frequencies. However if you do hear any of them, we are always interested in signal reports. Please email your reports/comments or questions to w3hms@aol.com.

This article, Building a Beacon for 2401 MHz has been published in the *CQ VHF Magazine*, Fall 2007 issue beginning on page 44, except for the "Update April 2008" portion of this article. K3VDB also presented it at the 2007 AMSAT Symposium before the addition of the third beacon.



Figure 7: First test in a tree at the W3MMV QTH.

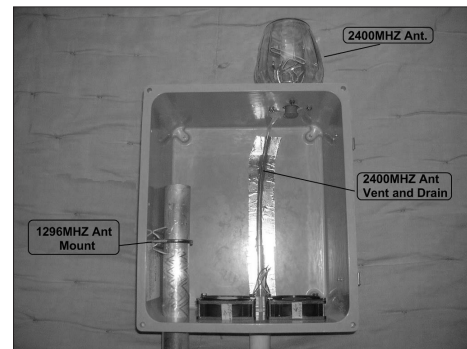


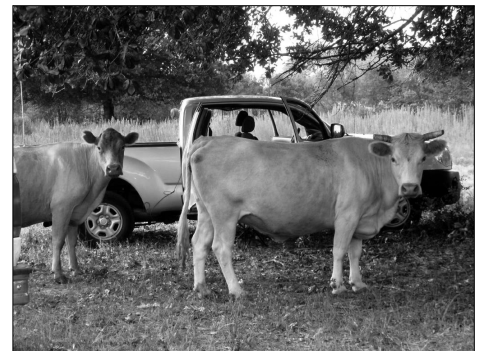
Figure 8: Beginning of the build.



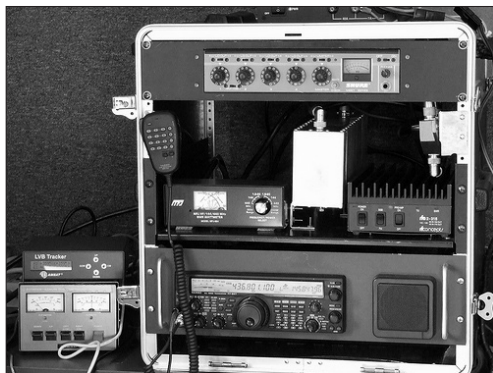
W5IU Antenna



Charlie, K5ENG, and Tom, K5SAF, straighten 2-meter antenna elements with advice from Michael, W2CVZ, and Laurie, K5LIB.



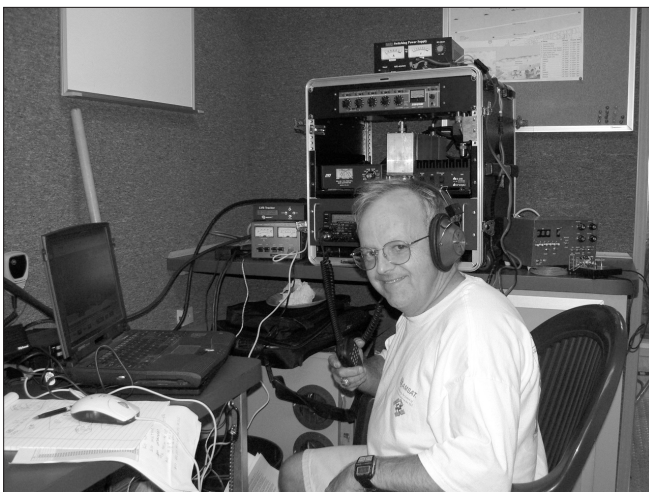
The "locals" at the Sparks' Ranch were well behaved this year.



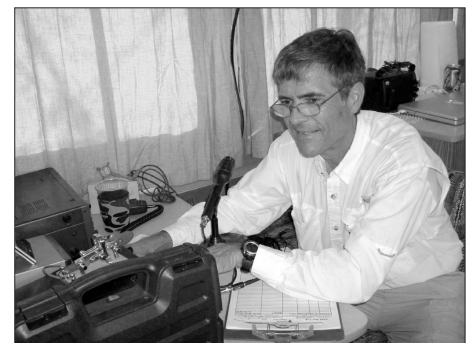
W9LJ Satellite operating position.



W5MSQ



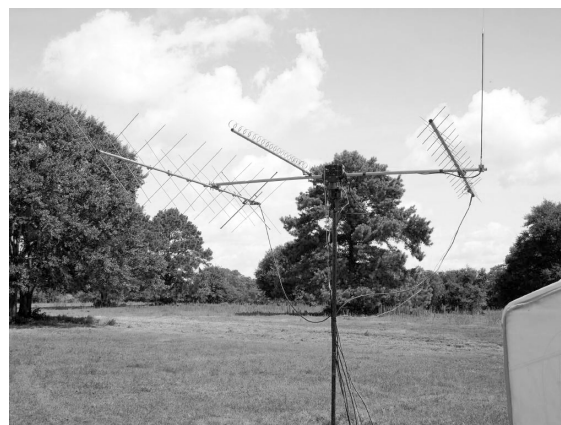
W9LJ FD2008 satellite operator AJ9N.



Andy, W5ACM, gets another hamsat QRP QSO for W5MSQ.



W9LDX



W5MSQ antennas.

Release for AMSAT on June 15, 2008: CFC Certification 2008

On June 13, 2008 the The Office of Combined Federal Campaign Operations issued the final draft of the listings for independent organizations that have been approved for participation in the 2008 CFC. The Radio Amateur Satellite Corporation (AMSAT) was again included in the approvals.

The CFC, or Combined Federal Campaign, is the U.S. Government equivalent of the United Way in the private sector. The campaign affords all US Government employees the opportunity to make donations from their regular paychecks to CFC approved charities. AMSAT has again successfully applied to CFC for that status and is grateful for the approval. This stamp of approval means that AMSAT has met the strict standards set by the U.S. Office of Personnel Management (OPM) assuring donors that our programs of work and financial operational standards meet the standards for expectable operations and programs.

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Gunther Meisse, W8GSM
Treasurer
AMSAT North America



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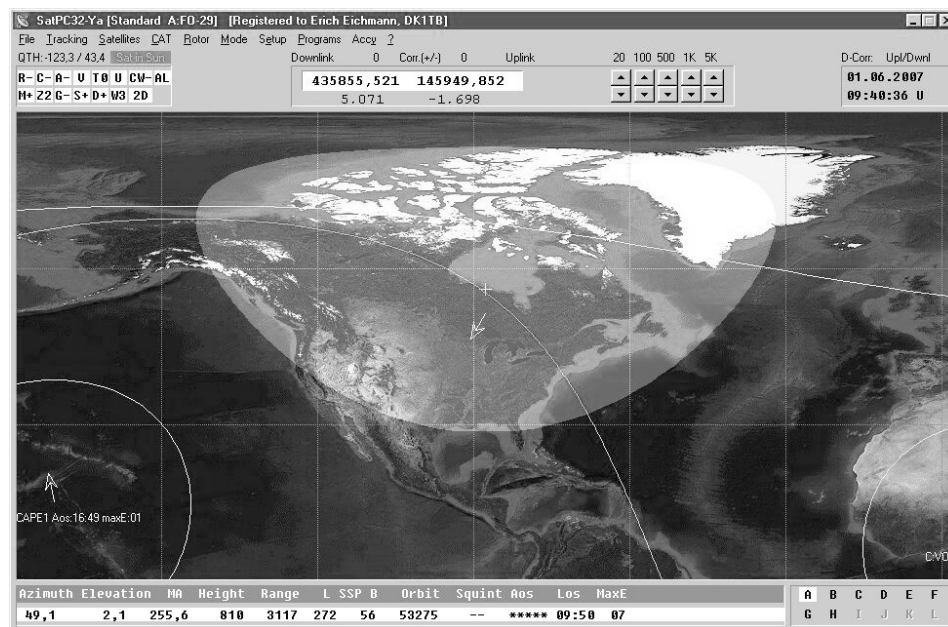
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The author DK1TB donated SatPC32 to AMSAT. All proceeds support AMSAT.





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Proposed Network-centric Architecture for the Advanced Communications Package (ACP)

by Timothy J. Salo, Salo IT Solutions, Inc.

Abstract – This paper suggests a system-level architecture for the Advanced Communications Package (ACP). The architecture presented here employs the lessons of the Internet architecture and leverages the Internet protocols to create a network-centric, system-level architecture for the ACP. This high-level architecture is developed by partitioning the required functionality into subsystems, defining interfaces between those subsystems and assigning the subsystems to hardware platforms. Following that, several fundamental design issues are highlighted and potential solutions to these challenges are outlined. The resulting system-level architecture should stimulate thought and discussion about the design of the ACP, and may provide a foundation for future ACP design and implementation efforts.

Introduction

The Advanced Communications Package is a novel, satellite-based, digital communications system that is enabled by software-defined radio (SDR) technology. The ongoing ACP design work has, up to this point, focused on the lowest communications layers and on the application layer. This paper examines everything that is architecturally in between the lowest communication layers and the ACP applications. The result is a proposed network-centric, system-level architecture. Important benefits of this proposed system-level architecture are that it:

1. Simplifies the design and implementation of the ACP system by placing clear boundaries on the ACP system.
2. Provides a general communications service that supports a broad range of applications, both those that are already planned, as well as not-yet-conceived applications.
3. Opens application development to any interested party by cleanly separating applications from the ACP communications services and by providing a standard interface between the two.
4. Leverages existing Internet protocols and the Internet architecture to enhance interoperability and reduce technical risk.
5. Helps to identify architectural and

design issues that warrant additional study.

The Advanced Communication Package (ACP)

The Advanced Communications Package (ACP) uses software-defined radio technology to provide a satellite-based, multi-user, digital communication system [1], [2], [3]. ACP ground stations transmit data to the on-orbit ACP payload on different channels. The ACP payload employs SDR technology to demodulate all of the uplink channels simultaneously. Packets received by the ACP payload on the uplink channels are statistically multiplexed onto a single downlink channel. Each ACP ground station extracts from the single, multiplexed downlink the packets in which it is interested. Figure 1 below illustrates how the ACP payload multiplexes packets received on different uplink channels onto a single, statistically multiplexed downlink channel.

An important design objective of the ACP project is to minimize the complexity of the ACP on-orbit payload. As a rule, intelligence should be placed in the ground stations, rather than in the ACP payload. Consistent with this objective, the ACP payload should do little more than forward packets from the uplink channels onto the downlink channel.

The ACP will support numerous simultaneous channels [5]. Each ground station will use

its own uplink channel (although the ACP payload won't be able to prevent ground stations from sharing an uplink channel, either inadvertently or intentionally). Multiple classes of ground stations will be supported. Less-capable ground stations will transmit at lower bit rates, while the ACP payload will encode packets destined for less-capable ground stations in a fashion that makes them easier to decode reliably. The ACP payload will forward fixed-length 225-byte packets.

The ACP system is being developed by the Radio Amateur Satellite Corporation – North America (AMSAT-NA). AMSAT anticipates that the ACP payload will be carried on either a high earth orbit (HEO) satellite or a geosynchronous earth orbit (GEO) satellite. Information about the project can be found on the AMSAT Web pages (<http://www.amsat.org/>).

Most of the design work on the ACP to date has focused on the lowest communications layers (e.g., modulation techniques and forward error correction (FEC) technology) and on the applications that will use the communications services provided by the ACP payload. This paper outlines a proposed system-level architecture that uses the lower-level services provided by the ACP payload to support ACP applications, both the applications that have been proposed, as well as those that have not yet been invented.

For the purpose of exploring a system-

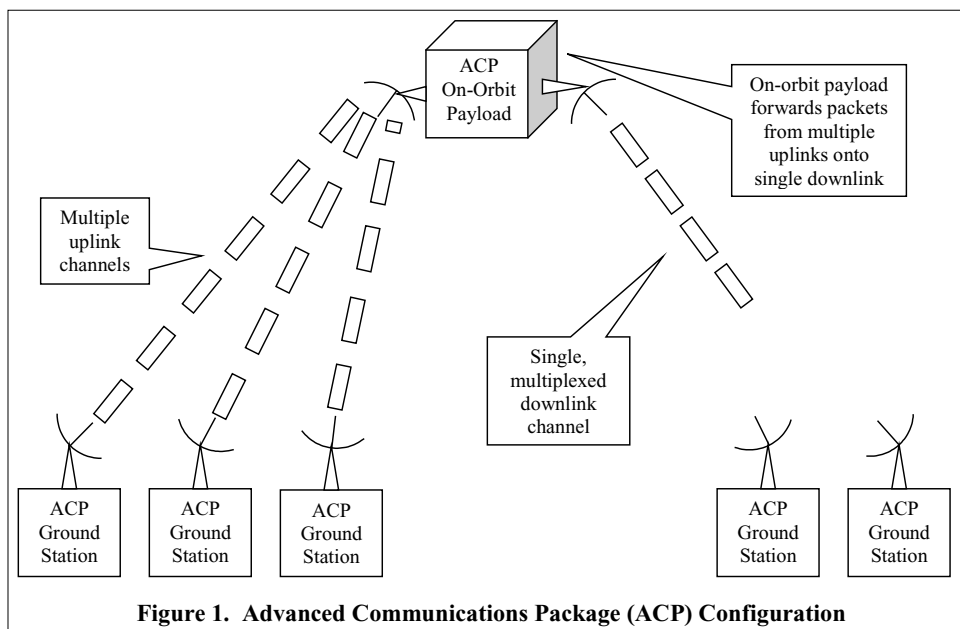


Figure 1. Advanced Communications Package (ACP) Configuration

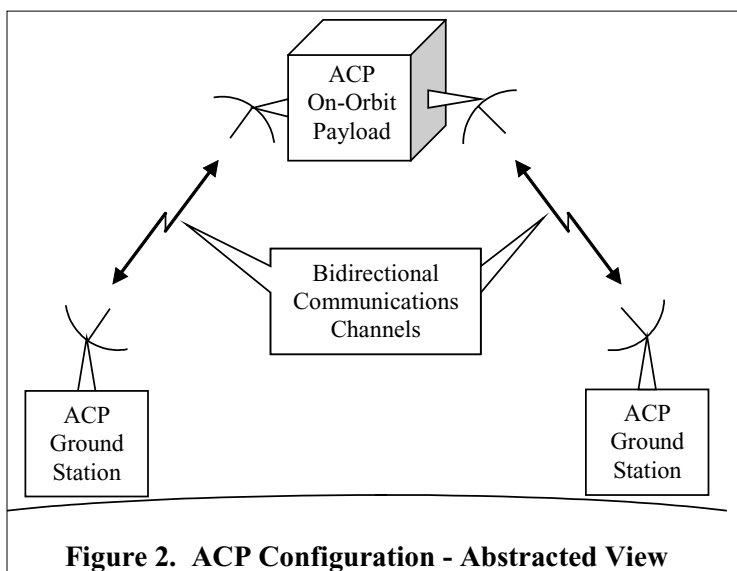


Figure 2. ACP Configuration - Abstracted View

level architecture for the ACP, it is useful to abstract away the details of the lower communication layers, such as how the uplinks and the down link are multiplexed and the details of the on-the-air encoding of bits and packets. In this abstracted view, illustrated in Figure 2, the ACP payload simply provides a bidirectional, packet-based, digital communications channel between two ground stations. With a

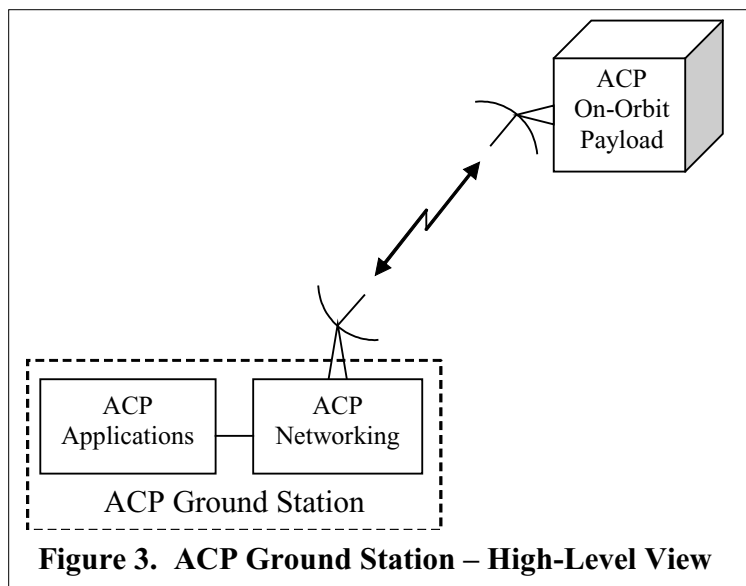


Figure 3. ACP Ground Station – High-Level View

little forethought, this simple model can easily be extended to include simplex communications (e.g., systems that transmit sensor data, but don't receive), point-to-multipoint communications (e.g., publish/subscribe disseminations models, such as RSS feeds) and multipoint-to-multipoint communications (e.g., full-duplex multiparty audio or video conferences).

Proposed ACP System Architecture: An Initial Refinement

Internet architecture is that it is often highly beneficial to separate the design and implementation of the network-related functionality from that of the systems that use the network [4]. Applying this widely employed architectural principle to the ACP ground station yields the structure shown in Figure 3. From this perspective, the ACP ground station is composed of two major

subsystems: "ACP Applications" and "ACP Networking". The ACP applications include those that are under consideration, such as text-based messaging, voice communications, and video conferencing [5]. The ACP architecture and implementation should also permit additional applications to be easily developed

in the future.

ACP System Boundary

Properly specifying the boundary of a system, deciding what functionality is provided by the system and what is not, is often critical to the success of a project. The system boundary shown in Figure 4 places the ACP applications *external* to the ACP system. In this view, ACP applications use the ACP system, but are not part of the ACP system. This architecture emphasizes the

The initial architectural design decisions segment the ground station two major subsystems, identify the boundary of the ACP system, and specify a standard interface between the ACP system and its users.

ACP Ground Station Architecture

An important lesson of the

ACP system as a networking solution that interconnects applications. (Note that the scope of the ACP Ground Station is smaller than is shown in the previous figure.)

ACP System Interface

A significant benefit of this particular specification of the ACP system boundary is that the ACP applications simply view the ACP system as a network that interconnects them with each other, a perspective summarized in Figure 5. The next fundamental design question is: What is the interface between the ACP applications and the ACP system? Describing the ACP system as a network makes one answer obvious: Use the Internet protocol (IP). Specifically, the ACP system forwards IP packets between end systems that host ACP applications. More directly, the ACP system appears to the ACP applications (and to the machines hosting these applications) to be simply an IP network.

Assigning Ground Station Subsystems to Hardware

The architectural decisions described above facilitate the implementation of the ACP applications and of the ACP ground station on different hardware platforms. The ACP ground station can be hosted on a machine that is tailored to its needs, without regard to the needs of the application software and conversely.

If the ACP applications and the ACP ground station are implemented on different machines, then the interface between them must include a physical link. Inasmuch as the applications and the ground station will exchange IP packets, the most general, applicable physical link is Ethernet. But, this shouldn't be a serious constraint: pretty much every readily available machine supports, or can easily be enhanced to support, an Ethernet interface and the IP protocol suite.

The machine selected for the ground station probably won't have a graphical user interface (GUI) or graphics hardware. And, the machine won't need a lot of memory (because it won't host the applications) and it might not even require a hard drive (perhaps using flash memory instead).

The machine that hosts the ACP applications can be, well, pretty much anything that is able to run the application software and that has IP software and an Ethernet interface. Presumably, most ACP applications will run under Windows or Linux, or under both. But,



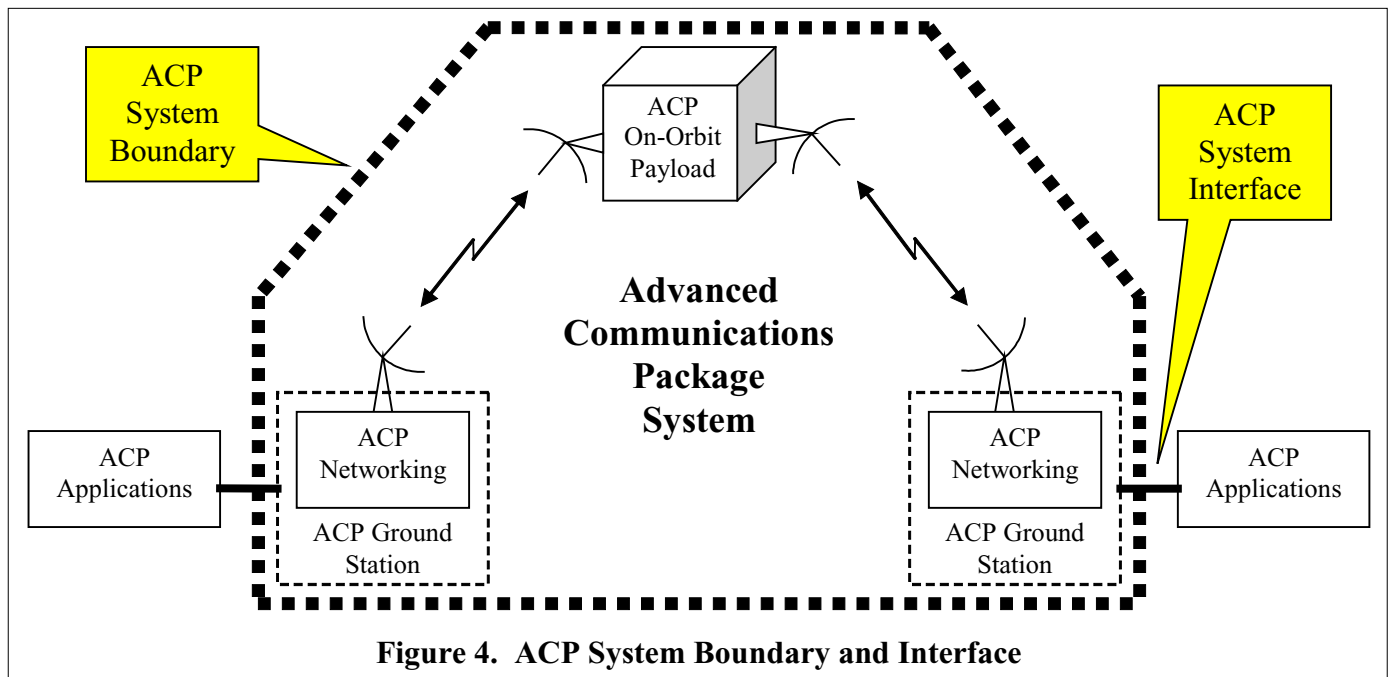


Figure 4. ACP System Boundary and Interface

the application developers are free to choose. In fact, the developers of each application are free to make their own choices about which machine, operating system, and development environment to use, provided that their choices support IP over Ethernet.

ACP System-Level Architecture

The system-level architecture proposed here can be summarized succinctly as: The ACP system appears to external devices to be an IP network. More emphatically, external systems are, for the most part, unaware that they are communicating over a satellite-based communications system, rather than over, for example, the Internet.

This architecture naturally divides the ACP development effort into three projects:

- **ACP Applications:** This project will develop applications that use the IP networking services provided by the ACP system. It should be staffed by software developers who think about

human computer interaction (HCI) and graphical user interfaces (GUI). This team will develop application software that runs under Windows, Linux and maybe even MacOS.

- **ACP Ground Station:** The objective of this work is to implement the functionality that makes the ACP system appear to external devices to be an IP network. This team will include developers who view the world in terms of packet formats and network protocols. The software they develop may operate in a more specialized environment, perhaps an embedded variant of Linux.
- **ACP On-Orbit Payload:** The ACP payload must operate in a very demanding, inaccessible environment. These developers will be concerned with creating highly reliable software that can operate onboard a spacecraft.

Fortunately, the functionality that this team must implement is limited to forwarding packets between the uplinks and the downlink, and perhaps a few other tasks that can't easily be performed elsewhere.

This proposed architecture makes the objective of the ACP development clear: the ACP system must look like an IP network; to its users, the ACP system must be *indistinguishable* from any other IP network. The test of whether the ACP development is complete and whether the development team has been successful is very simple: Does the ACP system exhibit the behaviors expected of an IP network?

This IP-based system architecture dramatically simplifies the development of ACP applications. To the extent that application developers are assured that the ACP system behaves like an IP network, they can develop and test their applications using any convenient IP network – like the Internet. If these applications work well over the Internet, but poorly with the ACP system, the first question should be whether the ACP system properly mimics the operation of an IP network. Of course, the ACP system *will* exhibit a few peculiarities that can't be controlled, such as high latency and perhaps high packet-loss rates. But, these unique characteristics can easily be identified. Furthermore, numerous techniques have been developed to mitigate the effects of high-latency paths and high packet-loss rates.

Another benefit of this architecture is that it

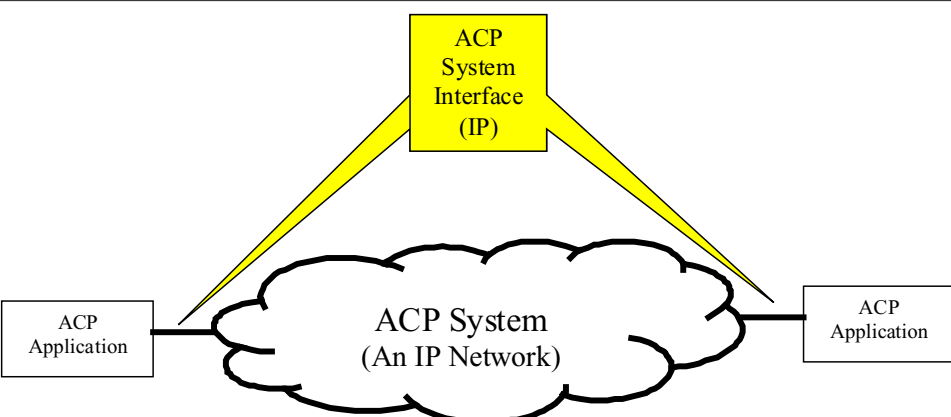


Figure 5. ACP Application Perspective of the ACP System

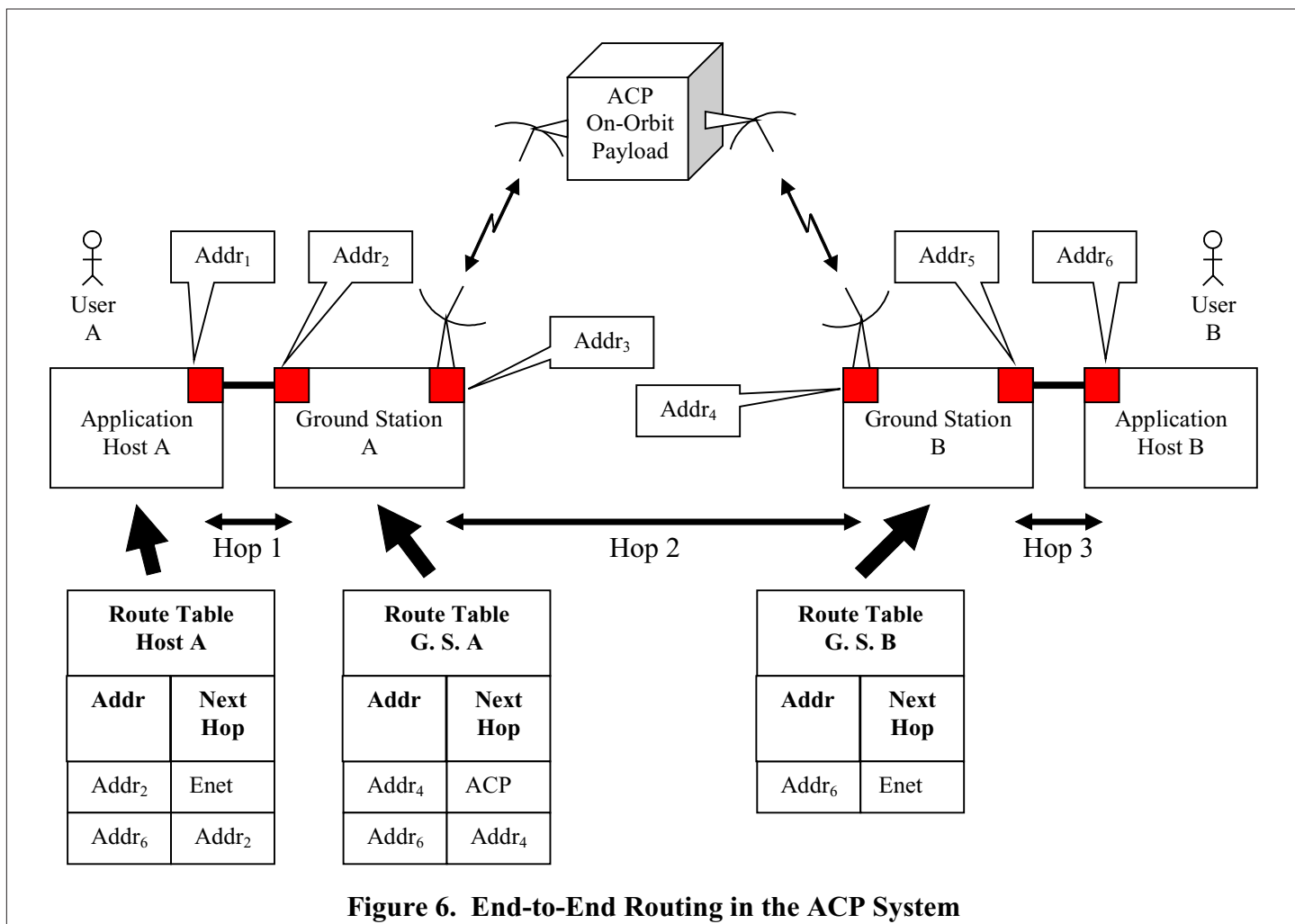


Figure 6. End-to-End Routing in the ACP System

makes it easy for applications to execute on existing machines. For users, deploying an ACP application should be no more difficult than installing a new software package on an existing machine (assuming, of course, that the machine is running a recent, common operating system and has adequate memory, storage and processing power). (Note that the ACP ground station networking functionality is likely to be deployed on a dedicated machine, but that is really an implementation decision that is up to the ACP development team.)

This architecture opens the development of new ACP applications to almost any motivated person or group. Little specialized knowledge is required, beyond that necessary to develop Internet-enabled software. And, no permission or special dispensation is necessary. The ACP system will transport any IP packets generated by an application, no questions asked. This open application development environment should stimulate the creation of numerous ACP applications, and may even attract new (and much needed) members to the Amateur Radio and amateur satellite communities.

By this point, it should be clear that even existing networked applications will be able to use the ACP system, and probably without modification. Some applications will require configuration, and some may require that servers be deployed. But, servers, whether they are Web servers or servers that support voice-over-IP (VoIP) networks, can use the ACP system as well – it's just another IP network. In fact, the ACP development team doesn't even need to implement any voice functionality – users could simply connect inexpensive VoIP phones or VoIP software (similar to the Skype software) to the IP services provided by the ACP system.

But, simply asserting that the ACP system will behave like an IP network doesn't mean that this is feasible, or even that it is possible. The remainder of this paper demonstrates the feasibility of this architecture by suggesting how the most significant functionality expected of IP networks might be provided.

Potential ACP Design Solutions

In this section, potential solutions are proposed for the most fundamental ACP

system design issues. What follows is *not* a proposed design for the ACP system. Rather, this material is merely intended to demonstrate the feasibility of implementing the network-centric, system level ACP architecture proposed above. The actual ACP system design may, in some cases, employ alternative technologies.

End-to-End Routing

The principle function of the ACP system is to forward IP packets between end systems, namely hosts running ACP applications. Figure 6 illustrates the end-to-end path between *Host A* and *Host B*, including the addresses assigned to interfaces and partial, stylized route tables. Readers with an exposure to IP routing should be able to convince themselves that this information is adequate to forward packets from *Host A* to *Host B*. The next challenge is to dynamically maintain the appropriate information in the route tables.

Active Ground Station Announcements

One way to construct the necessary route tables is for every active ground station to

periodically transmit Active Ground Station Announcements via the ACP payload. Perhaps, a special control channel could be dedicated to this function. If these announcements contain the following information, then every ground station will be able to create an up-to-date route table for the whole system:

- **Ground Station Address:** The address of the ground station's ACP interface would be announced. Using the example above, *Ground Station A* would include its address (Addr₃).
- **Ground Station Name:** Ground stations could be assigned names, as well as addresses. Perhaps, these names could be of the form *host.call.amsat*.
- **Host Address and Name:** The other ground stations also need to know about the hosts to which this ground station can connect. In this example, the announcements created by *Ground Station A* might include an address/name pair something like (Addr₁, "HostA.ab0do.amsat").
- **Text Description:** While names are more informative than addresses, descriptive text might be even more useful. Perhaps, this example announcement will include the following text: "ACP design video conference". Or, perhaps this sort of information could be disseminated in an Available Resource Announcement.
- **Transmitter Identification:** While the precise requirements for transmitter identification warrant additional study, the call sign of the transmitting station might also be included in this announcement (e.g., "AB0DO").

Each ground station could use a traditional routing protocol (e.g., the Route Information Protocol, RIP) to distribute the route information learned from the Active Ground Station Announcements to the hosts to which it provides service. Note that this Active Ground Station Announcement also provides some other capabilities that will be discussed shortly.

Resolution of Names to Addresses

Humans generally prefer domain names (e.g., "www.amsat.org") to numeric IP addresses (e.g., 128.54.16.15). The Active Ground Station Announcement described above could be used to make the devices in the ACP system appear as if they were part of the Internet Domain Name System (DNS). Each ACP ground station could implement

a DNS resolver, software that translates domain names into numeric IP addresses. Hosts that want to use the ACP system (e.g., machines that host ACP applications) would consult the ACP resolver any time that they need to translate a DNS name to an address. The ACP resolver would translate ACP names (e.g., names of the form *host.call.amsat*) to IP addresses, based on information learned from the Active Ground Station Announcements. The ACP resolver would forward traditional DNS names to Internet DNS servers. As a result, applications could treat names assigned to ACP devices as if they were Internet domain names. In fact, the applications won't even know whether a name is associated with an ACP device or with a traditional Internet device.

Segmentation and Reassembly (SAR) Protocol

Because ACP packets are much smaller than IP packets, a simple protocol is required to segment IP packets into multiple ACP packets, and to reassemble those ACP packets back into an IP packet. The ATM Adaptation Layer 5 (AAL5) may provide a useful example.

Uplink Channel Status Announcements

ACP ground stations will need to determine which uplink channel they should use. One approach is to let each ground station pick a channel that doesn't appear to be currently in use, and then deal with any collisions that might occur. Uplink Channel Status Announcements, messages that describe the status of the uplink channels, could be transmitted on the downlink periodically. Perhaps, each packet on the downlink could include the number of the uplink channel on which it was received. A single control ground station could monitor the downlink channel and periodically transmit Uplink Channel Status Announcements on the uplink channel, enabling every ground station to easily learn the status of the uplink channels.

Conclusion

This paper proposes a network-centric, system-level architecture in which the ACP system provides general networking services to its users, ACP applications. By appearing to be an IP network, the ACP system can support existing Internet-enabled applications, as well as open the development of new ACP applications to any interested party. This model has applicability well beyond satellite communications. It is beneficial to terrestrial

wireless digital communication systems that use technologies similar to the ACP. In fact, this model is useful for *any* digital communications system. The benefit is the same: nearly any existing Internet-enabled software or device can, with minimal effort, use the services offered by these communications systems.

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All radio amateurs, worldwide, are cordially invited to participate in AMSAT's Straight Key Night (SKN) on OSCAR 2009.

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In keeping with the friendly nature of this event, all participants are encouraged to nominate someone they worked for "Best Fist." Your nominee need not have the best fist of those you heard, just of those you worked. Please send your nomination to w2rs@amsat.org. A list of those nominated will appear in ANS and *The AMSAT Journal*.

CU SKN!

Ray Soifer, W2RS

New AMSAT Journal Assistant Editors

The AMSAT Journal has two new assistant editors! I am quite excited to announce that JoAnne Maenpaa, K9JKM, and Tim Lilley, N3TL, have joined the *Journal* staff. JoAnne is one of the former *Journal* editors and has served AMSAT in many ways over the years. She also works with the AMSAT News Service. Tim is new to the *Journal* and works in the publishing field and brings very good experience to the staff.

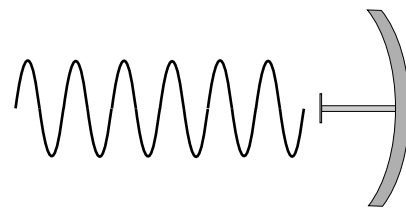
JoAnne will manage files and help with electronic editing as well as with gathering articles for the *Journal*. Tim will work on the editorial schedule and will help rustle up articles for the *Journal*.

I am grateful that they have volunteered to help. We will work hard to get the *Journal* back on schedule and make it even better for the membership. Of course, Bill Hook, W3QBC, continues his absolutely excellent work as a proof reader and editor.

I look forward to working with the new team. Your comments about the *Journal* are always welcome at journal@amsat.org.

Ed Long, WA4SWJ

Editor, The AMSAT Journal



WA3GOV SK

It is with great sadness that I report the death of Howard Ziserman, WA3GOV, at the age of 55. For many years Howard served as the Area Coordinator for Maryland & Virginia. He volunteered for EVERY hamfest in this area, sometimes traveling from over 100 miles away. He had a love for the space program working at the NASA Bioprocessing and Pharmaceutical Research Center in Philadelphia in the early 80's. When he moved to Maryland in 1989, he combined his love of education and space to work on Space Shuttle Mission STS-94 and later on the ARISS program. Howard had a B.A. from Cornell, a B.E. in EE from Johns Hopkins, an M.S. in Chemistry from the University of Maryland. His dream was to get his Ph.D. and so he left Maryland in 2001 for Kansas City. There he received this degree from the University of Oklahoma in December of 2006.

Martha, AMSAT Manager



Howard Ziserman, WA3GOV, (left) with Owen Garriott, W5LFL, former NASA astronaut.



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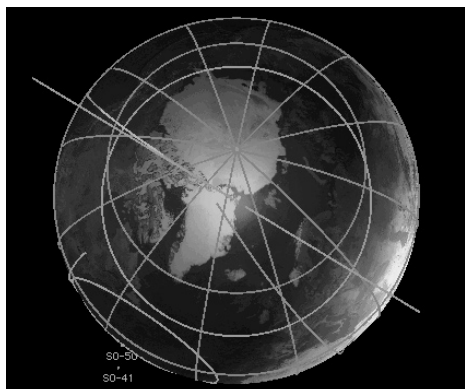
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'Spacey' Christmas Shopping

by Tim Lilley, N3TL, n3tl@amsat.org

Here are some ideas to serve as the start of a "spacey" Christmas shopping list.

AMSAT Membership – Give memberships to your non-satellite operating friends and ask for a renewal of your own membership as a gift. Because you're reading this article, you likely already know how valuable the *Journal* is in providing information to help you make the most of your satellite operations. So you not only give an entertaining and educational gift, but you support AMSAT's primary mission of keeping Amateur Radio in space.

Handheld Satellite Station – This is the most expensive item on the list, but it's not as pricey as you might think. You can assemble a fully functional handheld station that will effectively work the FM satellites in low earth orbit (i.e., a dual-band, dual-receive, VHF/UHF handheld radio with a handheld satellite antenna) for less than the cost of an xBox 360 game console and 2-3 games. Look at Yaesu's FT-60 HT and any of the antennas mentioned below to hit that price point, or pay a little more to get more features with an Icom IC-92AD, Kenwood TH-6F or Yaesu's VX-7R or new VX-8R.

Handheld GPS – Look on eBay for used Garmin GPS III Plus units, or consider one of Garmin's new Oregon or Colorado series of handheld units. All of them include the option of displaying maidenhead grid squares. Thanks to Glenn Miller, AA5PK, whose QSL card from a recent trip to DM90 for some satellite passes introduced me to this neat feature.

Antennas – If you already have an HT that is capable of working the FM LEO satellites, the Pryme AL-800 whip will get you into the satellites effectively for roughly \$35 retail. It's not the same as a handheld Yagi like the Arrow 10WBP (\$140) or the Elk log periodic (\$90), but it works surprisingly well. For proof, visit Allen F. Mattis' (N5AFV) Web site at www.qsl.net/n5afv to read about Allen's success in making thousands of contacts with an HT and AL-800.

Software – SatPC32 provides tracking and computer control of your radio(s) and antennas, and the license fee that a North American pays goes to support AMSAT. Not only is it a useful gift, but the purchase helps keep Amateur Radio in space! 🌐

Apogee View - continued from page 3...

Pastor of Good Shepherd Lutheran Church, Westborough. Unfortunately, the move has precluded me from installing an Amateur Radio station due to town restrictions on towers. Meanwhile, I have the ability to work the FM LEO satellites giving demos at ham club meetings and hamfests. Hopefully, I'll be able to get on the air occasionally with an HT and Arrow antenna.

As we transition into 2009, AMSAT is looking at a number of challenges and potential opportunities. At the board of directors meeting, the board modified our Vision Statement. The new statement is:

"Our vision is to deploy satellite systems with the goal of providing wide-area and continuous coverage. AMSAT will continue active participation in human space missions and support a stream of LEO satellites developed in cooperation with the educational community and other amateur satellite groups."

The key changes from the previous statement that was developed in 2004 are:

- Remove dates from the vision statement and focus on the end result
- Remove the term 'HEO' to reflect the fact that we will accept a variety of launch opportunities, such as Rideshare and MEO as well as HEO as the cost of projects (launches) drives our options.
- Emphasize 'wide-area' and 'continuous coverage' to reflect the fact that we will focus on one launch opportunity at a time. Previously, we aimed for a 'constellation' of HEO satellites (including P-3E which hasn't launched) to provide 'continuous coverage' worldwide.

Clearly, the new vision statement incorporates changes based upon experiences of the past four years as well as changes in the space industry and external environment that impact our ability to place a communications package in orbit.

During the 2008 Annual Meeting that was held on Saturday morning, October 25th during the Space Symposium, I outlined some of the disappointments of 2008 and listed some goals for 2009. My presentation is available for download from the AMSAT Web site as a PDF file (link is on the main page). Please feel free to review it. While the 'bullet points' provide key comments, the presentation doesn't have the 'talking points' that I made during each slide, so

please be aware of this limitation when reviewing the material. We made the Annual Meeting available via EchoLink, and we had members listening 'live' and submitting questions during the meeting. Thank you to those individuals who participated in the Annual Meeting.

In subsequent 'Apogee View' columns I will go into greater detail on our 2009 goals, but as a starter, here is the list that I presented at the Annual Meeting:

- AMSAT Must Re-Establish Momentum
- Complete SUITSAT-2!!
- Further Refinement of K3IO's Comm Package
- Pursue 'Modularization' Approach-OTS availability
- Fund Raising—Satellite Development and Launch
- Develop an ITAR Strategy
- What to do with the AMSAT Lab?
- Encompass Educational Initiative
- Enhance AMSAT's Information Technology
- Recruit a New Generation of Volunteers
- Encourage Mentorship
- Work with other Organizations

As you can see, we have significant challenges but also new opportunities. While 2008 has been disappointing, we do have the ability to make things happen in 2009.

Finally, please don't hesitate to contact me directly if you have suggestions, comments or concerns that you would like to share. I will make every effort to respond to e-mails that I receive, but please keep in mind that I am on the road extensively which may limit my ability to quickly respond. Please know that I read every e-mail that I receive from AMSAT members and that I appreciate every person's willingness and time spent to share their thoughts and suggestions.

73,

Barry A. Baines, WD4ASW
AMSAT President 🌐



Please support AMSAT-NA.
Thanks!



Space Radio for Windows by Anthony Monteiro, AA2TX, AA2TX@amsat.org

Abstract

Space Radio is a very low-cost way to receive the voice and data transmissions from the International Space Station on the 2M band. It can also be used to receive the packet data satellites that operate on this band. Using about \$15 in parts and free, open-source software, Space Radio could offer an attractive entry point for students, hobbyists, and Amateur Radio operators interested in exploring space communications and software radio technology.

Introduction

The Amateur Radio on the International Space Station (ARISS) school contact program has been an outstanding success with hundreds of schools participating and providing an enriching science experience for thousands of students. But, what happens next? No doubt, the afterglow of excitement lasts for several days or even weeks. But once the ham volunteers pack up their equipment, the majority of students will likely have little or no continued exposure to ham radio, space communications or ARISS.

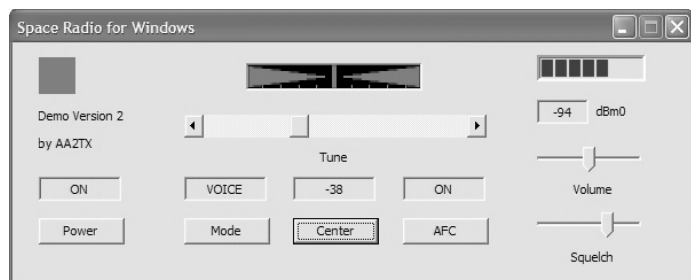


Figure 1: Space Radio for Windows control panel.

And while the hundreds of school contacts are an impressive achievement, there are more than 160,000 elementary, middle and high schools in the USA alone [1]. This means that only a very minute percentage of students will ever be able to participate in the school contact program. The goal of this project was to investigate the potential of software radio technology to make ARISS communications more accessible.

Software radio technology has historically been driven primarily by common carrier and military applications where the higher costs of a software-based radio has been offset by the desirability of higher performance and increased flexibility and this has generally been true of Amateur Radio applications as well. But Space Radio uses the exact

opposite approach. It employs software radio technology as a way to reduce costs while providing sufficient but modest performance and flexibility.

ARISS and Packet Satellite Communications

The transmissions from the ISS and packet data satellites on the 2m band use narrow-band, frequency modulation (FM) with a channel bandwidth of 16 kHz. Packet data is modulated on the FM downlink as audio frequency shift keying (AFSK) at 1200 bits per second using the Bell 202 modem standard.

Table 1 provides the key characteristics of the downlink of the ISS and some representative packet satellites. Due to the Doppler shift, the downlink carrier frequency shown in the table will be seen at the ground station to vary by about ± 3 kHz.

The signal level seen at the ground station depends upon the satellite range, (the ISS being included as a satellite,) its transmitter output power, its antenna gain and the gain of the receiving antenna. Based on the information

available, the nominal received signal levels of each satellite were calculated. This calculation assumes the lowest transmit power available is used and that the receive antenna is polarity matched with a gain of 0 dB. The results are shown in Table 2 for satellite elevation angles of 0 degrees, 20 degrees and 90 degrees (i.e., overhead).

As can be seen from the table, the signal from the ISS is fairly strong. Using the International Amateur Radio Union (IARU) recommendation for S-units, the ISS would

Satellite	Mode	Carrier Frequency (MHz)	Transmit Power (Watts)	Satellite Antenna Type	Estimated Antenna Gain (dB)
ISS	Voice	145.800	5-25	¼-wave whip	0
ISS	Packet	145.825	5-25	¼-wave whip	0
PCSAT	Packet	145.827	3	¼-wave dipole	2
RAFT	Packet	145.825	1	Short whip	-2

NOTE: Raft has re-entered and is listed only for reference.

Table 1: ISS and packet satellite downlink summary.

be received between S7 and S9 so the receiver sensitivity should not need to be very high to hear the ISS signal. The packet satellites are up to 10dB weaker so they would require higher receiver sensitivity or a gain antenna to allow decoding the AFSK data.

It is important to note that the antenna polarities will generally not be matched due to Faraday rotation unless using a handheld antenna that can be manually pointed. The table provides a starting point for estimating the receive signal levels but the real levels will depend upon the actual receiving antenna system.

Major Project Goals

The main purpose of this project was to test and demonstrate the feasibility of using software radio technology to create a low-cost, 2m FM receiver capable of monitoring ARISS voice transmissions. The target audience was intended to include high school and perhaps advanced middle school

Satellite	Altitude (Km)	RX Signal 0 degrees (dBm0)	RX Signal 20 degrees (dBm0)	RX Signal 90 degrees (dBm0)
ISS	360	-105	-98	-90
PCSAT	800	-109	-104	-97
RAFT	360	-114	-107	-99

NOTE: RAFT has re-entered and is listed only for reference.

Table 2: ISS and satellite receive signal levels.

students as well as electronics hobbyists and ham radio operators. This wide audience

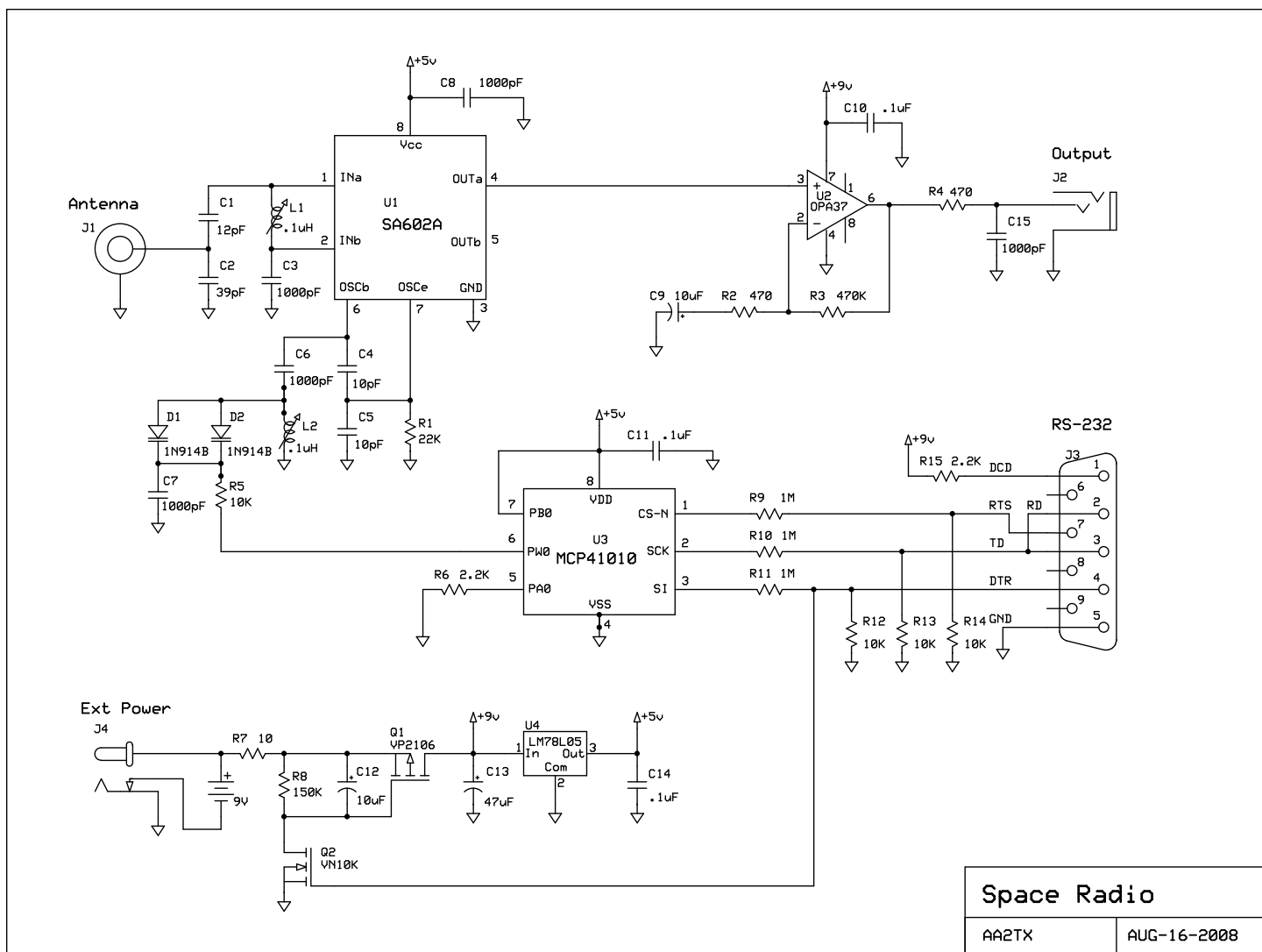


Figure 2: Space Radio schematic diagram.

constrains certain aspects of the project.

First of all, the required circuit would have to be very easy to build. This was taken to mean no surface-mount parts could be used. The circuit would need to be as simple as possible keeping the parts count low and the parts had to be readily available as well. Since this project could be offered in a kit form, there was not a hard requirement to have parts available in single unit quantities however, this was a secondary goal.

Next, the costs had to be kept low. The electronic components cost goal was \$25 or less not including any battery, enclosure, cables, etc. Additionally, all software including all development tools were required to be free. This would allow anyone to re-use or re-design any aspect of the hardware or software if they were interested. The Space Radio for Windows source code will also be freely available in keeping with the above.

Finally, Space Radio was intended to be sufficiently sensitive to allow monitoring ARISS voice transmissions using only an omni-directional antenna. A secondary goal was to allow sufficient tuning range and sensitivity to allow receiving packet data transmissions from the ISS and digital satellites with at most a small hand-held beam.

System Design

Any system design requires making tradeoffs. The key design tradeoffs for Space Radio included trying to minimize the circuit complexity and component cost while maintaining adequate performance. The following system parameters were established:

1. Sensitivity: 10dB Noise Figure or better. This is needed to allow receiving ISS voice with an omni antenna.
2. Input impedance: 75 ohms. This allows good performance using cheap RG-6

TV coax and a dipole antenna, but will also work fine with 50 ohm coax.

3. Intermediate frequency: 8.82 KHz. This IF is approximately in the center of a typical PC sound card pass-band and is conveniently 1/5 of the maximum sample rate.
4. Use simple (not image-reject) mixer. With the low IF, the image is in the adjacent channel. Since the ISS and satellites are in the space sub-band, there should be little or no activity in the channel adjacent to the ISS or satellites.
5. Use free-running tunable oscillator with automatic frequency control. This keeps costs down and allows automatic Doppler correction once the signal is acquired.

continued on page 27 ...



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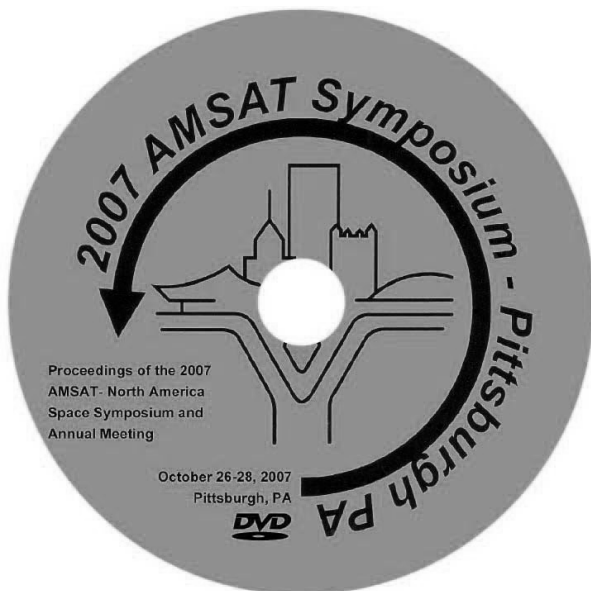
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6. Radio will be completely controlled from the PC without even an ON/OFF switch. This is cheaper and more convenient.
7. Use a COM port for PC control of radio. USB would be better, but is not reasonable without using surface-mount parts.
8. Use LINE-IN or MIC port on PC for radio IF signal. As above, USB would be better, but is not reasonable without using surface mount parts.
9. Radio audio plays through PC speakers.
10. Battery operated with optional AC adapter.

Circuit Design

The Space Radio circuit was designed to meet the system design parameters specified above. Please see the schematic diagram of the Space Radio circuit shown in Figure 2.

The antenna is connected to J1, a 75 ohm F-connector. C1, C2, and L1 provide a match from 75 ohms to the input impedance of U1 as well as providing out-of-band signal filtering. U1, an SA-602A, is a double-balanced mixer IC in an 8-pin DIP package. This device provides a noise figure of around 6 dB and about 15 dB of conversion gain. It also includes an extra transistor that is used in this circuit as a Colpitts local oscillator. The base local oscillator frequency is determined by C4, C5, and L2. L2 has an aluminum tuning slug which is adjusted for a nominal local oscillator frequency of 145.813 MHz.

Note that L1, the RF input coil, also has a tuning slug. The RF circuit bandwidth is wide enough so that it does not need to be precisely tuned.

D1 and D2, a pair of ordinary 1N914 diodes, are used as variable capacitors to provide radio tuning. The circuit provides about +/- 25 kHz of tuning range. The local oscillator is normally tuned 8.82 kHz above or below the received signal. This provides an intermediate frequency (IF) centered at 8.82 kHz at the output of U1.

The IF signal is applied to U2, an OPA37 ultra-low-noise op-amp in an 8-pin DIP package. U2 and its associated circuitry provide 60 dB of gain over the range of 50 Hz to 20 kHz. The output of U2 is fed to a 3.5 mm stereo jack making it convenient to connect it with a standard patch cable to the LINE-IN jack on a PC sound card. Only

the LEFT channel is used (i.e., the TIP.) If a LINE-IN jack is not available, the MIC jack may also be used, but this may result in lower fidelity of the received audio.

The tuning of Space Radio is accomplished by changing the bias on the tuning diodes via U3. U3 is an MCP41010 digital potentiometer in an 8-pin DIP package. The potentiometer side of U3 is at pins 5, 6, and 7 with pin 6 being the wiper. One end of the pot is connected to 5 volts and the other end is connected to ground through resistor R6 to limit the minimum bias to about 0.9 volts. Adjusting the wiper changes the bias on the tuning diodes which changes their capacitance and the local oscillator frequency. The MCP41010 device has a Serial Peripheral Interface (SPI) port to control the position of the pot wiper. This is a synchronous interface with 0 and 5 volt digital levels. Since most PCs do not have an SPI port, Space Radio uses a regular PC COM port with special *bit-banging* [2] driver software to implement the SPI protocol. The COM port RS-232 levels are converted to SPI-compatible levels using the resistor network consisting of R9 through R14.

Space Radio is powered by a standard 9-volt transistor radio battery. It draws less than 10 milliamps when turned on so a battery can last quite a long time when it is used only for ISS voice monitoring. For extended operation, J4 is provided to allow using an AC adapter. Space radio will operate over the range of 7.5 to 12 volts.

Power to Space Radio is controlled by the PC COM port via the DTR lead. When the radio is disconnected or the DTR lead is low (-12V), transistor Q2 is turned off which turns off pass transistor Q1. When the DTR lead is set high (+12V), Q2 is turned on which charges capacitor C12. This turns on pass transistor Q1 which connects the 9V supply to the radio circuits. The 9 volts is also applied to U4, an LM78L05 low-power, 3-terminal, 5-volt regulator IC which provides a stable voltage for the SA-602 mixer and the MCP41010 digital potentiometer.

Parts and Assembly

The complete list of the electronic components is shown in Table 3. To keep the shipping costs low, almost all of the parts were purchased from one supplier; Mouser Electronics [3]. The prices shown in the table are the single quantity prices and were the actual prices paid to construct the prototype unit. In larger quantities, the prices could be significantly lower.

The one part not available from Mouser is the oscillator coil, L2. This part is only available Coilcraft [4], its manufacturer. This part was selected because it uses an aluminum tuning slug which has a zero temperature coefficient. Fortunately, this company offers free samples in small quantities to students and design engineers. Please see their Web site for more details. As an aside, several Coilcraft inductors flew in space on the NO-60 "RAFT" satellite (see Table 1) and they performed flawlessly.

Unfortunately as of August 2008, one of the parts, the OPA37GP op-amp, was back-ordered at Mouser until January 2009. However, Digi-Key [5] had thousands of these in stock as part# OPA37GP-ND at the same price. Another alternative would be the Linear Technologies [6] LT1037CN8 which is an exact replacement. This part is actually cheaper but has a 2-piece minimum order from the manufacturer.

The Space Radio prototype was constructed on a printed circuit board ordered from ExpressPCB [7]. This company offers free schematic capture and printed circuit board (PCB) layout design software, which can be downloaded from their Web site. Since only a very small number of boards were needed for a prototype, the "MiniBoard" service was used. The prototype boards were ordered without solder masks or silk screening. A photo of the assembled prototype circuit board is shown in Photo 1.

Software Design

The Space Radio software is a 32-bit Microsoft Windows application. It requires Windows 2000 as a minimum and will run on any later version as well. All of the software was written in C++ and was developed using Visual C++ 9.0 Express Edition which is available for free from Microsoft [8]. The free Express Edition does not include a resource editor, which allows graphically creating and editing icons, dialog boxes, menus, and other visual resources used in a Windows program. These can be created using a text editor, but it is very tedious. Instead, a free resource editor, "ResEdit" was downloaded and used [9].

Please see the software architecture diagram shown in Figure 3. The software consists of four major modules; the User Interface, a WAVE I/O Driver, a KISS-RX Driver, and the IF System.

The User Interface module, like a typical Microsoft Windows application program,



Part ID	Description	Mouser Part#	QTY	Cost Each \$	Cost Total \$
B1	9V Clips	121-0426/I-GR	1	0.29	0.29
C1	12pF (NPO)	140-50N5-120J-TB	1	0.06	0.06
C2	39pF (NPO)	140-50N5-390J-TB-RC	1	0.06	0.06
C3,6,7,8	1000pF	140-50Z5-102M-RC	4	0.07	0.28
C4,5	15pF (NPO)	140-50N5-150J-TB-RC	2	0.06	0.12
C9,12	10uF/16V tantalum	80-T356E106K016AT	2	0.48	0.96
C10,11,14	.1uF	581-5ZH104MACJI	3	0.14	0.42
C13	47uF/16V electrolytic	647-UVR1C470MDD1TD	1	0.03	0.03
D1,2	1N914B	512-1N914B	2	0.03	0.06
J1	F-Connector	601-25-7630	1	0.92	0.92
J2	3.5 mm stereo jack	161-3507	1	0.71	0.71
J3	2.1mm power jack	163-5004-E	1	0.63	0.63
J4	DE-9 Female	152-3409	1	1.09	1.09
L1	.1uH	434-1012-3.5CS	1	0.61	0.61
L2	.1uH	***** see Note 3 *****	1	3.02	0.00
Q1	VP2106	689-VP2106N3-G	1	0.34	0.34
Q2	VN10K	689-VN10KN3-G	1	0.32	0.32
R1	22K	660-MF1/4LCT52R223G	1	0.04	0.04
R2,4	470	MF1/4LCT52R471J	2	0.04	0.08
R3	470K	660-MF1/4DCT52R4703F	1	0.03	0.03
R5	47K	660-MF1/4DCT52R4702F	1	0.03	0.03
R6, R15	2.2K	660-MF1/4DCT52R2201F	2	0.03	0.06
R7	10	660-MF1/4D52R10R0F	1	0.02	0.02
R8	150K	660-MF1/4DCT52R1503F	1	0.03	0.03
R9,10,11	1M	660-MF1/4DCT52R1004F	3	0.03	0.09
R12,13,14	10K	660-MF1/4D52R1002F	3	0.02	0.06
U1	SA602A	771-SA602AN/01	1	2.25	2.25
U2	OPA37GP	595-OPA37GP	1	2.56	2.56
U3	MCP41010	579-MCP41010-I/P	1	1.70	1.70
U4	LM78L05	863-MC78L05ACPREG	1	0.20	0.20
		Total Cost			14.05

Note 1: All caps are 50V ceramic disc unless otherwise noted.

Note 2: All resistors are 1/4-watt.

Note 3: L2 is a Coilcraft, 5mm, shielded, tunable RF inductor. Part# 164-07A06SL. See text about free samples.

Note 4: Optional 9V, AC adapter is also available from Mouser Electronics. Part# 552-PLA01A-090-R at a cost of \$5.29 each in unit quantities.

Table 3: Parts List.



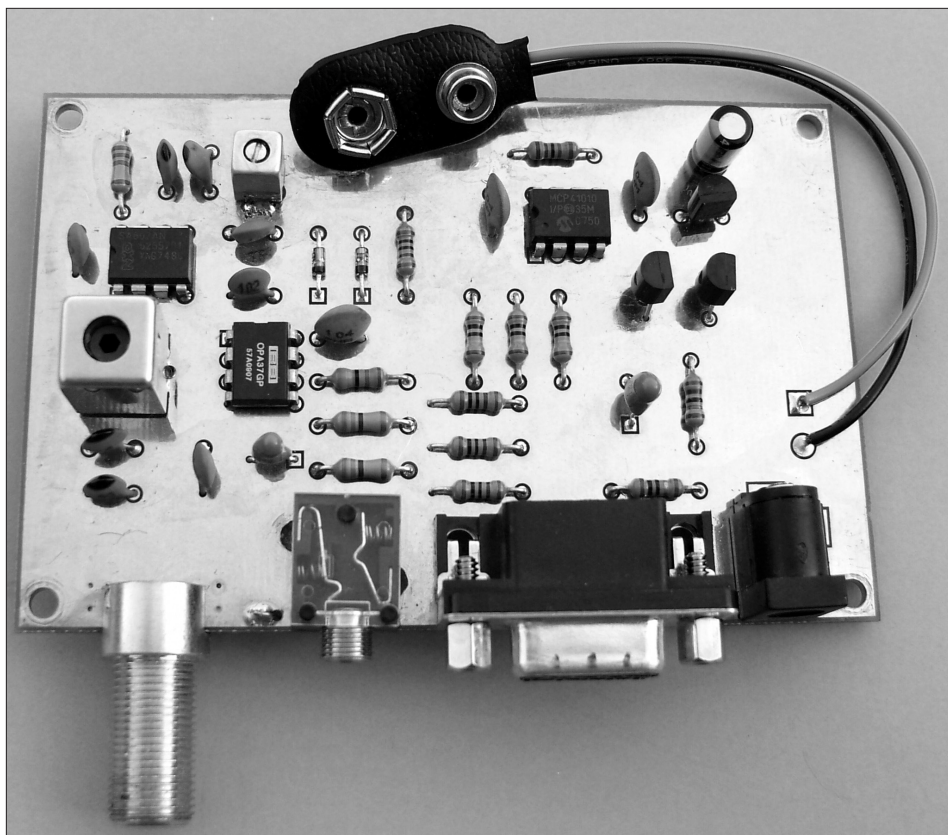


Photo 1: Space Radio prototype circuit.

includes window controls and display components. These are used to interact with and control the operation of Space Radio. And, like all Windows applications, the main window provides the entry point for the program and also ties all the other modules together. Unlike a typical Windows

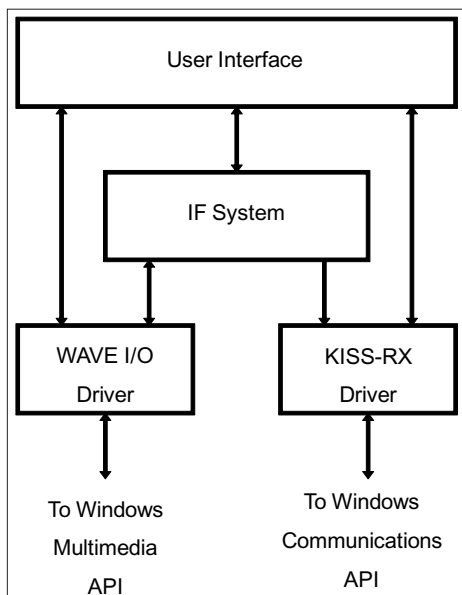


Figure 3: Space Radio software architecture.

application however, Space Radio uses a Dialog Box as its main window. This allows the use of a graphical editor to draw the display area and place the controls which is

better suited to a radio "Front Panel."

The WAVE (waveform audio) I/O Driver provides a simple interface to the Windows multimedia Applications Programming Interface (API). This hides the messy details of the low-level code to drive the sound card and helps simplify the interface to the other modules. The WAVE I/O Driver provides a simple pointer passing mechanism to blocks of PCM samples.

The KISS-RX Driver runs the Space Radio circuit (nicknamed KISS-RX for "keep it

simple...") including power and frequency control. It implements the special bit-banging software to run the SPI protocol over the COM port and converts frequency control commands to the low-level SPI operation and parameter codes needed by the digital pot on the Space Radio circuit board.

Finally, the IF System is the signal processing component of Space Radio. It works much like an intermediate frequency (IF) sub-system IC as found in a typical hardware radio but of course all of the signal processing is done in software.

Digital Signal Processing

The signal processing software in the IF System module is the heart of Space Radio. A block diagram is shown in Figure 4. As shown in the diagram, 16-bit, Pulse Code Modulation (PCM) samples arrive from the sound card at a 44.1K samples/second rate. This is the highest rate that a typical built-in sound card will support. Fancy sound cards will do higher rates but they are not generally included with a typical PC.

The input samples are passed to the Power Detector which measures the average power in the input signal. The calculated power is converted to decibels and drives the Received Signal Strength Indicator (RSSI.)

The input samples are also passed to a x256 sample rate converter which includes an up-sampler and linear interpolator. This converts the sample rate to a little over 11M samples/sec. This high rate is needed by the FM demodulator block to provide good fidelity FM detection.

The next stage is the FM demodulator and it

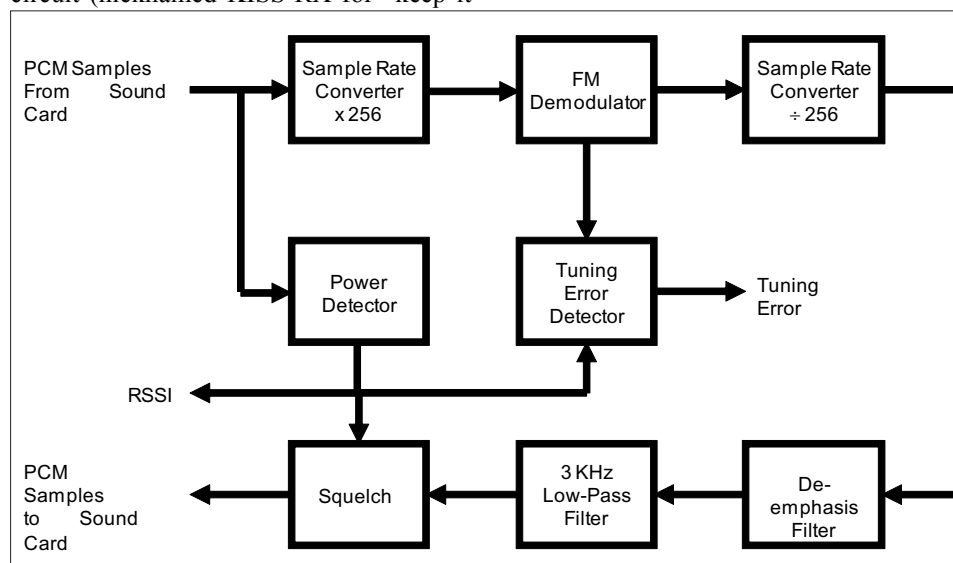


Figure 4: Digital signal processing.

uses a zero-crossing detector with a period to frequency converter. The zero-crossing detector counts the number of samples in-between signal polarity changes which provides the instantaneous period of the input signal. The period is then converted to the frequency deviation from the IF center frequency. A zero-crossing detector is used because it has excellent noise rejection without needing a limiter stage and is simple to implement.

The output of the FM detector feeds a sample rate converter block which reduces the sample rate back to the sound card rate of 44.1 K samples/second. This block consists of a 2's compliment integrator, a divide-by 256 rate decimator, and an N=10 comb filter. This function is commonly called a cascaded integrator-comb (CIC) decimator.

The sample rate converter is followed by an N=8, CIC low pass filter which functions as a de-emphasis filter. This filter uses the same cascaded integrator-comb structure as the sample rate converter but with no rate decimator. Though it does not have a perfect de-emphasis shape, it does provide nice sounding audio.

The de-emphasis filter is followed by a 3 kHz infinite-impulse response (IIR) low-pass filter. An IIR low-pass filter works much like an analog resistor-capacitor network and it cleans up any left-over, high-frequency digital processing artifacts without affecting the audio quality.

The recovered audio is then passed through a squelch process before being passed back to the sound card. The squelch block will mute the audio if the received signal strength is below the squelch set level. The squelch may be disabled if desired. Note that there is no volume control block needed. Speaker volume is controlled by sending software commands to the PC sound card.

Finally, the Tuning Error block uses the RSSI signal from the Power Detector and takes zero-crossings from the FM detector to create an output signal that corresponds to the average frequency tuning error when a valid signal is present. This is much like the discriminator-meter output from an FM sub-system IC and it is used to drive the front panel discriminator meter. This signal is also used to provide automatic frequency control of the radio's local oscillator. In this way both oscillator drift and received signal Doppler-shift can be compensated for automatically.

Operation

Space Radio will run under Windows 2000 or later operating systems. On the author's PC, a 2.3 GHz Pentium R running Windows XP, Space Radio requires about 2% of the CPU.

Operating the Space Radio control panel is pretty much like operating any other radio. Please see the control panel image in Figure 1. The user controls include buttons for POWER, MODE, CENTER, and AFC. There is a scroll bar for tuning and sliders to adjust the squelch and the volume. An S-Meter shows signal strength and there is a direct digital readout of the received signal power. A discriminator meter at the top center provides a visual indication of the tuning error. Most of these controls are self-explanatory (i.e., the POWER button toggles the power on and off.)

Tuning Space Radio is accomplished by adjusting the scroll bar labeled "Tune." The box under the scroll bar shows the number of tuning steps from the center frequency. A step is about 200 Hz and the range is +/- 127 steps. The scroll bar thumb can be moved directly by left clicking it and moving it via the mouse. Clicking on the area between the scroll bar ends and the scroll thumb changes the frequency by five steps. Clicking the arrows on the scroll bar ends changes the frequency by one step. The CENTER button returns the scroll thumb back to the scroll bar center position.

The MODE button selects VOICE mode at 145.800 MHz or PACKET mode on 145.825 MHz. The MODE button does not change the radio tuning; it selects high or low side local oscillator injection which allows double the frequency coverage. It was also envisioned that this would activate an AFSK demodulator when in PACKET mode, but this software was not completed at the time this paper was written.

The AFC button toggles the automatic frequency control on or off. To use AFC, first adjust the squelch slider to fully mute the audio. Then click the AFC button to turn it on. The radio can then be tuned using the tuning controls. When the radio detects a signal stronger than the squelch level, it will lock on to it automatically. When the AFC is engaged, the software internally saves the squelch level that was set so the squelch slider can be re-adjusted as desired or even disabled and it will have no affect on the AFC action. The AFC will correct for

Doppler-shift on a received signal so that no manual re-tuning is normally necessary once the desired signal is acquired.

Lab Testing

The receiver sensitivity was tested using a combination of HP-8903A and HP-8640B test sets. The receiver required 1.8 microvolts at the input for 12 dB SINAD using a 1 kHz modulation tone and 1.67 kHz deviation (i.e., 100% NBFM modulation.) This is equivalent to -104 dBm0 and is well within the expected sensitivity requirement for monitoring the ISS voice and data transmissions with an omni-directional antenna.

On-The-Air

On August 13, 2008, an ARISS school contact was made with the Town of Berkeley Heights, NJ, Summer Playground Camp. This contact was successfully monitored with Space Radio from the Boston, MA area. The antenna was a Lindenblad connected through 200 feet of coax with no preamp.

This pass had a maximum elevation angle of around 45 degrees. Signals from the ISS were detectable at around 10 degrees elevation at 2 minutes into the pass, but were very noisy. At 20 degrees elevation, about 3 minutes into the pass, the signals became very clear and fully readable. There were a few short fades during the pass probably due to nulls in the Lindenblad antenna pattern but these were only a few seconds in duration.

The maximum observed signal level was -96 dBm0 and remained fairly constant over the pass between the 20 degree elevation points. This is well within the predicted levels when the antenna elevation gain pattern, mismatched polarity loss and coax losses are considered.

Once the signal was acquired, Space Radio's automatic frequency control successfully maintained the correct tuning over the approximately +/- 3kHz Doppler shift observed over the pass and no manual tuning was needed.

Since the ISS has not been active in packet mode, it was not possible to test packet data operation on the air. However, the receiver sensitivity measured in the lab test and the performance demonstrated during the school contact appears to be more than sufficient for this to work.

Discussion

This project is not sufficiently developed to consider this paper a construction article. The major purpose was to see if software radio technology could be used to make a



Tool Use	Name	Web Address
Circuit Simulation	LTspice/SwitcherCAD III	www.linear.com
Schematic Capture	ExpressSCH	www.expresspcb.com
PCB Layout	ExpressPCB	www.expresspcb.com
SW Development	Visual C++ 9.0 Express Edition	www.microsoft.com
Resource Editor	ResEdit	www.resedit.net

Table 4: Free development tools.

really cheap, 2-meter FM radio that could receive the ISS Voice signals. While this was successful, more development work is needed before it could be considered a “turnkey” construction project.

For example, the local oscillator has no temperature compensation. While this worked fine for the demonstration, it is probably not as stable as needed to be really useful. This does not necessarily add anything to the cost but it does require more development work.

Another issue is that the ISS has not been in voice mode very much and the lack of activity reduces the usefulness of Space Radio as a construction project. Perhaps further developing the data capability would make it more interesting as the ISS, PCSAT and a number of other digital satellites such as PCSAT2, RAFT and ANDE, have been much more active on packet in the recent past. Focusing on packet data however might require an increase in the receiver sensitivity as the cubesats are considerably weaker than the ISS. This could be accomplished at a fairly minor cost by adding an RF amplifier stage but there would be an increase in the difficulty of building the circuit. For some satellites, even this might not be sufficient as decoding the data from RAFT and ANDE required having a preamp at the antenna even with an FT-847 radio when using an omnidirectional antenna. Perhaps an “active” antenna or a cheap antenna mounted preamp is a better solution.

Yet another issue is the printed circuit board cost. If at least 100 of these were made, the cost would be less than \$5 per board, even with solder-mask and silk screening added. So, a kit might be a good option. But the “MiniBoard” service

that was used to make the prototype at \$51 for 3 boards is probably too costly on its own. Another alternative might be to re-layout the board as single-sided-only and offer it through a hobbyist oriented supplier like Far Circuits [10].

As long as these and other issues are kept in mind, anyone who is interested and wants to build a copy of Space Radio to try it out and do their own experiments is encouraged to do so. The Space Radio software, schematics, and printed circuit layout files will be made available to anyone who requests them via e-mail.

Free Development Tools

One of the things that worked very well on the Space Radio project was the reliance on free development tools. All of the tools used can be downloaded via the Internet. Table 4 provides a list of the tools that were used and their sources.

Conclusions

The goal of the Space Radio project was to investigate the application of software radio technology (SDR) to make a really low-cost receiver for the ISS. This is unlike typical SDR applications which focus instead on high-performance or enhanced flexibility. The Space Radio experiment was a success. The astronauts on the ISS could be clearly heard during a scheduled ARISS school contact on the prototype radio built for under \$15 in parts.

While Space Radio is not sufficiently developed to consider it a construction project, it is hoped that the successful demonstration of the concept would be thought-provoking. There are many areas where a limited performance but really cheap radio could be useful and the basic circuit can be used up through 500 MHz. Some other versions could include an APRS monitor, a NOAA Weather radio, an aircraft receiver, or even just a monitor for a favorite 2-meter repeater.

Most recently, there has been significant SSTV activity from the ISS. If this was expected to be continued, an SSTV demodulator could be added

to allow watching these transmissions (i.e., make it into “Space TV”). Or, with a small change to the oscillator circuit, Space Radio could be used to monitor the university Cubesats that have 70cm downlinks. Comments, discussion and suggestions are welcome.

Tony Monteiro, AA2TX, was first licensed in 1973 as WN2RBM and has been a member of AMSAT since 1994. He started his engineering career as a member of the technical staff at Bell Laboratories and has served as an engineering director at a series of high-tech start-up companies. Contact him at AA2TX@amsat.org.

Footnotes

- [1] Number of public schools from www.publicschoolreview.com. Number of private day schools from www.privateschoolsreview.com
- [2] Bit-banging refers to a method of implementing a serial interface by individually setting I/O port bits on and off in software.
- [3] Mouser Electronics orders can be placed online at www.mouser.com.
- [4] Coilcraft parts are available from www.coilcraft.com.
- [5] Digi-Key parts can be ordered from www.digikey.com.
- [6] Linear Technologies parts and information are available at www.linear.com.
- [7] ExpressPCB software and printed circuit boards are available at www.expresspcb.com.
- [8] Visual C++ 9.0 Express Edition is available from www.microsoft.com.
- [9] ResEdit Resource Editor is available from http://resedit.net/.
- [10] Far Circuits circuit boards are available at www.farcircuits.net.





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